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Supplement to THE RAILWAY GAZETTE, January 6, 1939

READING ELECTRIFICATION, SOUTHERN RAILWAY

SUPPLEMENT TO THE RAILWAY GAZETTE

69

Electric Railway Traction

PUBLISHED EVERY FOURTH WEEK

FRIDAY, JANUARY 6, 1939

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Electric Railway Traction

Lapland Iron Ore Transport

THE general characteristics of the Lulea—Kiruna—Narvik electrified line in Lapland, belonging to the Swedish State Railways between Lulea and Riksgraensen, and to the Norwegian State Railways from the latter place to Narvik, is well known, but adjoining it at Kiruna is an extensive electrified network serving the ore workings. Underground, the tracks are laid to a gauge of 600 mm., and are operated on the 600-volt d.c. system, with overhead current collection, by four-wheel locomotives driven by two 26-h.p. nose-suspended motors. The broken ore is transported in side tipping cars with a capacity of 2½ tons. The standard-gauge main-line ore cars are backed into the main loading tunnels of the workings, of which there are two, each 16½ ft. high by 16½ ft. wide, separated by a 16-ft. wall. There are four loading pockets, and the ore is fed into the cars through doors operated by compressed air. Normally, 26 cars are backed into the tunnels, but the ore trains worked by the single-phase 16-kV. 16⅔-cycle electric locomotives over the 105 miles from Kiruna to Narvik are made up to 50 six-wheeled cars of 35 tons capacity, which run on roller bearings. At Luossavaara, on the other side of the lake, there are further iron ore deposits, and the ore is recovered partly from open-cut and partly from underground workings. The broken ore is handled first by four-wheel 600-volt d.c. electric locomotives, and taken to chutes which discharge it into main-line ore cars on a branch line running from Kiruna. The power for these plant railways, for the whole mining and quarrying establishment, and for the Swedish section of the main line railway is obtained from the Porjus hydro-electric station. Shunting at Narvik wharves is carried out by 0-6-0 steam and electric locomotives, and the 2-ft. gauge store-tipping lines at the dumps are worked by four-wheeled diesel and electric locomotives.

Rubber for Individual Axle Drives

AMONG the numerous points of interest in electric locomotive design brought out in the discussions in London and Glasgow on Mr. C. E. Fairburn's paper before the Institution of Electrical Engineers (see issue of this Supplement for April 29, 1938) was the performance and design of the springs incorporated in individual axle drives. Mr. J. E. Calverley mentioned the short life (40,000-50,000 km.) of some of the laminated springs used in the Bianchi drive in Italy compared with what is obtained with the helical steel springs in cup-type drives. Some endeavours have been made to use rubber springs of the Silentbloc pattern, and these have an advantage over certain cruder applications in that the rubber is shrouded by steel cups, and the rubber thus has not to slide over the steel faces of the wheel or spider. Two express locomotives on the Region du Sud-Ouest (ex P.O.-Midi) of the French National Railways have been fitted with these bushings. The first has the Sécheron type of drive; hinged Silentblocs are applied at the point of suspension of the helical steel springs, and are believed to have materially reduced the stress due to lateral forces and have assisted in damping out forced vibrations. The second example makes use of Silentblocs between the links and pins on the quill and wheels of a link drive, and the locomotive fitted has run over 200,000 miles with satisfactory results. Finally, 11 of the latest GG1 2-Co + Co-2 single-phase express locomotives of the Pennsylvania Railroad have had rubber blocks substituted for the original helical steel springs, but at the moment there is no information available as to the behaviour.

8,000-h.p. Electric Locomotive

THE first of the new high-power 15-kV. single-phase electric locomotives of the German State Railway was put into trial service during December, after a brief ceremony at the Hennigsdorf works of the builder, the A.E.G. Known as Series E.19, the new class has the same 1-Do-1 wheel arrangement as the previous E.18 class, hitherto the most powerful electric tractor on the Reichsbahn. Although prepared specifically to cater for the conditions obtaining on the Nuremberg—Halle main line, the electrification of which is nearing completion, the new locomotives will be suitable for express train haulage on the Bavarian and Silesian divisions also. On the Nuremberg—Halle route E.19 locomotives will be expected to haul unassisted 360-ton trains over the steep grades—up to 1 in 40—in the Thuringer Wald near Probstzella, and also to haul a similar weight over level sections at a top speed of 150 km.p.h. (93 m.p.h.). The equipment is believed to be suitable for hauling such trains at well over 160 km.p.h. (100 m.p.h.) and, indeed, speeds of 220-225 km.p.h. (136-140 m.p.h.) have been spoken of as possible maxima during special trial runs. The electrical equipment has been designed to enable an eight-car FD train of 360 tons weight to be accelerated from rest to 180 km.p.h. (112 m.p.h.) on straight level track in 4½ min. The combination of electric and air braking on the locomotive, in conjunction with the air brake equipment used on the FD trains, is expected to be sufficient to stop the complete train from 180 km.p.h. in 900 m. (985 yd.) under similar track conditions. The output on the continuous rating is approximately 5,000 h.p. and the maximum output over 8,000 h.p.; at starting the tractive effort is about 60,000 lb. At the moment, locomotive E.19.01 is being run by the Munich division of the Reichsbahn, and trials are being conducted on braking, and on current collection and adhesion between wheel and rail at high speeds. Compared with the preceding E.18 class, the new locomotive has an increase of 30 per cent. in the continuous rating, and a similar increase in maximum output and in starting tractive effort. The increased tractive effort is particularly interesting, because the adhesion weight has gone up very little compared with the 79 tons of the E.18 class. In the earlier stages of design the Reichsbahn and A.E.G. engineers had the collaboration of the late Dr. Walter Reichel, one of the most celebrated German electric traction engineers, who, incidentally, was closely connected with the Marienfelde-Zossen high-speed electric tests of 1903-04.

SOUTHERN ELECTRIFICATION TO READING

Extension at a cost of £1,000,000 of the world's greatest low-voltage d.c. electrified railway system

ON January 1 electric traction was inaugurated officially on the Virginia Water—Ascot—Reading; Ascot—Ash Vale junction; Frimley junction—Pirbright junction; and Guildford—Aldershot North junction lines of the Southern Railway, on that company's standard 660-volt third rail d.c. system. Known generally as the Reading extension, the scheme provided for the conversion of 43 route or 88 track miles, bringing the Southern Railway totals up to 664 and 1,665 miles respectively. Many engineering works have been undertaken in connection with the scheme, most of them being of a light nature such as platform lengthening, new footbridge construction, and the rearrangement of tracks. The principal engineering feature has been the complete rebuilding of Ascot station, including the provision of a new double-track loop giving access from the main platforms to the Camberley line, and the construction of a new signal box.

Supply and Distribution

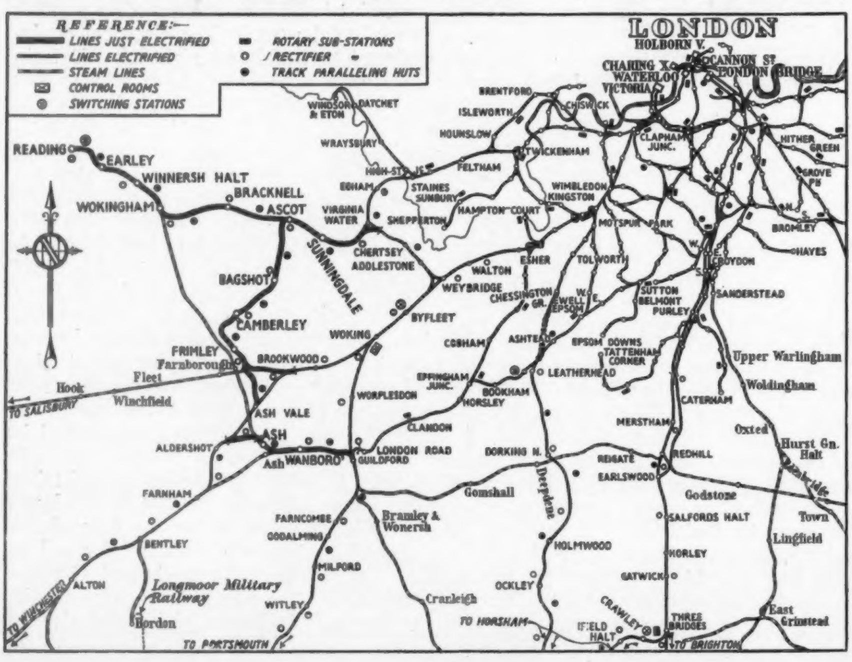
From the point of view of the supply and distribution system, the new extension is an addition to the existing network provided for the main-line electrification to Aldershot and Virginia Water, carried out in 1937 concurrently with the main line to Portsmouth, for which the main source of power supply is taken from the C.E.B. substation at Byfleet. By introducing a new source of supply from the C.E.B. Reading substation, the new extension provides a further alternative source of supply to the Alton and Portsmouth line. The connection into the existing Pirbright substation also has the effect of reducing the long stub-end feed which originally extended from Byfleet C.E.B. to Alton substation.

The 33-kV. power cables comprise three single-core unarmoured lead-covered cables as distinct from earlier schemes where a 3-core armoured cable was used. The three separate cables are laid simultaneously, and the three separate joint boxes are kept close together and neatly disposed so that the normal wooden troughing need be only slightly increased in dimensions. The method of laying or supporting the cables, as well as the pilot and supervisory cables, is also identical to that used on previous schemes, but the cables to Reading C.E.B. substation were laid along the main Great Western Railway line, to which this substation has direct access. All e.h.t. cables are 0·10 sq. in. in section, with the exception of the Sturt Lane—Pirbright link, which is 0·20 sq. in. in section; altogether 114 single core miles were used.

Substations

Ten new substations have been constructed, *viz.*, at Knowle, Ascot, Bagshot, Camberley, Sturt Lane, Bracknell, Wokingham, Winnersh, Reading, and Wanborough. Midway between each of these substations there is a track-paralleling hut. The substations and track-paralleling huts are unattended and are operated by supervisory control from Woking, where the existing control room has been extended to house the additional equipment required.

In addition to the equipment of the ten new substations, extra switchgear was provided at the existing Chertsey and Pirbright substations, where the new supplies were introduced into the existing system. This work was carried out without interference to the normal traction or signalling supplies given by these substations. The new substations have been positioned at regular intervals based on technical and natural conditions, so that they dovetail into the existing system. Their sites call for no special remark except those for Knowle and Ascot. It was necessary in the first case to cut back a bank very considerably, and at Ascot the site, which was some 30 ft. below rail level, had to be piled because of the unsatisfactory

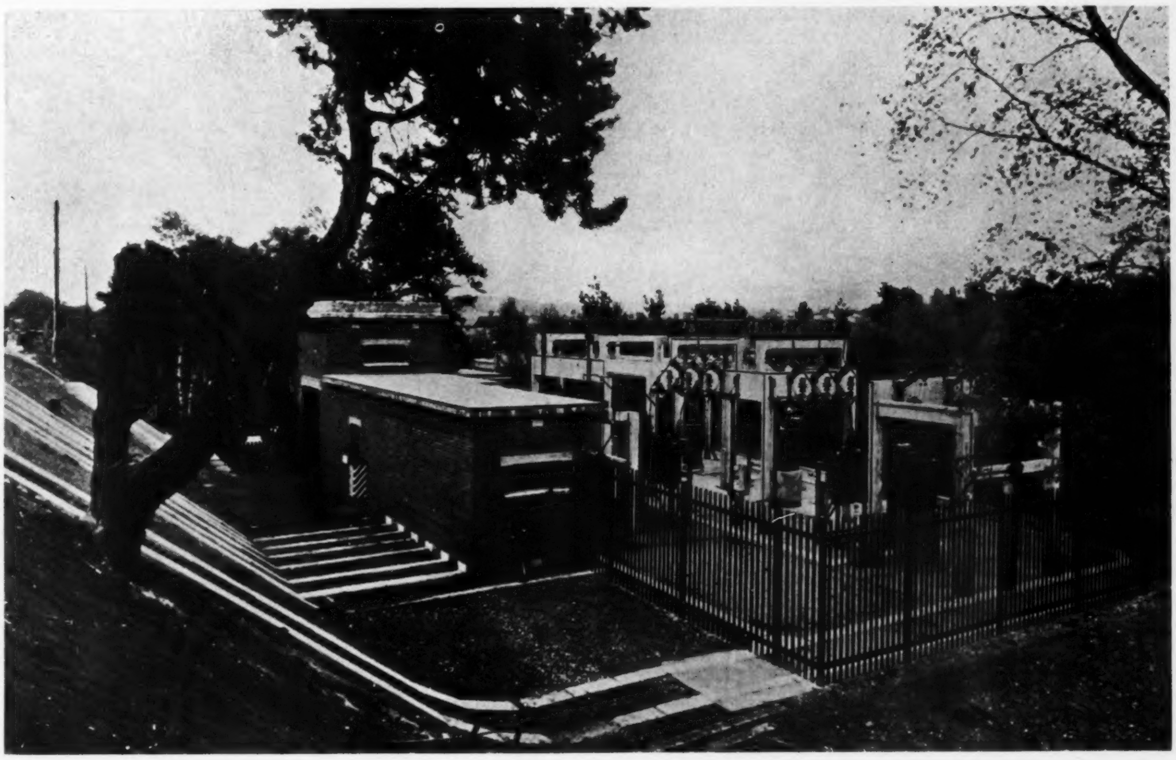


Map of the recently electrified Southern Railway lines in the vicinity of Reading, Ascot, and Aldershot, showing the location of the substations and the new power supply point from the grid at Reading, which forms an alternative source of supply to the Alton and Portsmouth electrified routes

foundation. The high-tension switchgear is all of the outdoor type and is supported on reinforced concrete structures. The standard arrangement comprises three 33-kV. oil circuit-breakers arranged as two incoming feeders with the third teeing-off to provide the supply to the mercury arc rectifier equipment. This equipment is housed in a separate building adjacent to the outdoor structure and the supply of energy is made available *via* a rectifier transformer standing outside one end.

The introduction of this new extension brings the number of rectifiers in service on the Southern system to 99. These are all of identical type, rated at 2,500 kW. continuously at 660 volts d.c. and they represent one of the largest, if not the largest, rectifier installations in the country. This unique position has provided the opportunity for gaining valuable experience in the maintenance of this class of plant which has an overall efficiency at full load of about 95 per cent. and slightly better than this at half-load. The mercury arc steel tank rectifiers are water-cooled from a self-contained circulating recooling system housed in a separate annexe to the main substation building. This, together with the special recooler for the high vacuum pump and other auxiliary equipment, requires a separate auxiliary supply of approximately 7 kW. This is obtained from a three-phase auxiliary transformer mounted on the outdoor switchgear raft, together with similar single-phase transformers which provide supplies for signalling and oil-switch motor operation. The rectified d.c. energy is distributed to the 660-volt conductor rails by high-speed circuit-breakers rated at 2,500 amp. each, and which can clear a short circuit in 0·02 of a second. These are housed in the substation building, which is designed in such a manner that all apparatus is mounted in the most convenient way for operation and maintenance.

Woking control room has been extended, and now has 65 panels with room for another 22, compared with the 40 panels installed previously. The building is 150 ft. long and 50 ft. wide, and the control room itself, of rectangular shape, has a maximum length of 90 ft. The room is artificially lighted by three inverted bowl pedestal lamp fittings, and an extra control desk has been provided to meet any future requirements. The control panels themselves are identical with those already existing and are arranged to represent in mimic form the whole of the main power circuits for the supply of electrical energy to the conductor rails. Each panel represents either a substation, track-paralleling hut, or C.E.B. supply substation, and from these panels the required switching operations at any of these points are carried out.



General view of the 2,000 kW. mercury arc rectifier substation at Ascot on the new Reading extension of the Southern Railway's 660-volt d.c. electrified system

The medium by which these operations are made is a selector system of remote control, which requires for its operation a transmitter at the control room and a receiver at the substation. These two pieces of apparatus are housed in cubicles with their attendant relays and other fittings, and each selector requires four conductors and one common return for its operation. Two substations are operated on each selector so that the total number of cores is consequently determined and grouped for convenience into one cable, which is looped into a number of substations in series. For this extension a 17-core and 12-core cable has been used.

Rolling Stock

The rolling stock provided for the Reading extension comprises 36 two-car corridor non-vestibuled trains of a

similar type to the 38 units provided for the extension of electrification to Portsmouth *via* Woking, and the 68 units for the extension of electrification to Portsmouth *via* Horsham.

Each unit consists of a motor-coach and a driving trailer. Two or more train units can be coupled to form longer trains up to a usual maximum of an eight-car train. Each coach is provided with a lavatory compartment at one end, and the lavatory hand basins have Heatrae storage-type electric water heaters mounted below. These heaters are thermostatically controlled and provide a source of constant hot water.

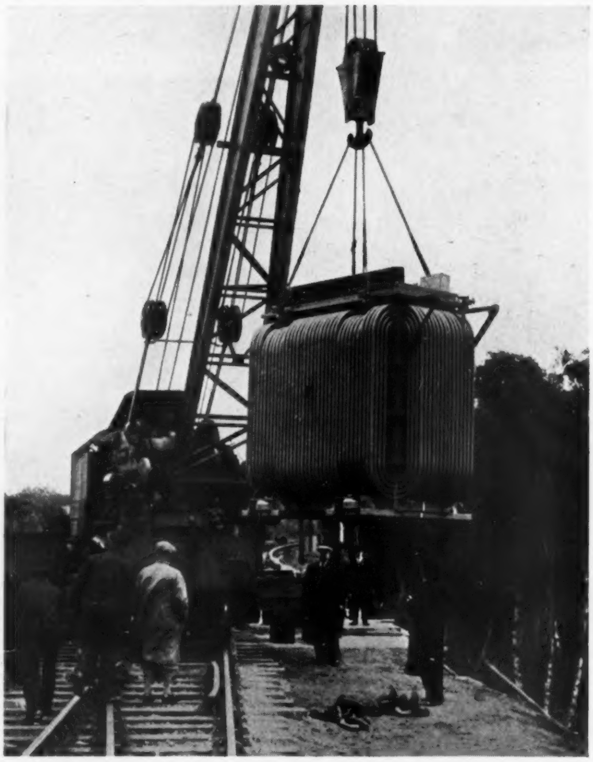
The electrical equipment of the motor-coaches includes two Type 339 totally-enclosed motors of 275 h.p. on the one-hour rating, mounted on the bogie at the leading end. These motors are of the type the Southern Railway has standardised for its suburban and main line semi-fast stock since the beginning of the electrification of its lines, and, including the motors provided for the Reading extension, there are now in use 2,500 motors of this type, totalling 687,500 h.p. The traction control equipment is of the underframe mounted electro-pneumatic unit switch type arranged for bridge transition. The low-voltage control circuits are fed from a potentiometer, and the control is arranged to multiple with the existing 660-volt electromagnetic equipments by means of four small train line contactors on each motor-coach.

Traffic Operation

The new electric services give improved facilities between London and Sunningdale, Ascot, Wokingham, and Reading, on the direct route, and between London and Bagshot and Camberley. The stations at Ash and Wanborough are linked up with the lines electrified in 1937 under the Portsmouth No. 1 scheme, thus enabling through electric trains to be operated from London to Guildford *via* Ascot and Aldershot.

Electrification has brought about an increase in frequency approximating to 80 per cent., with an acceleration of about 10 min. from London to the stations on the newly-electrified sections. As with all other Southern electrifications, the timetables have been skilfully drawn up on the basis of regular times at each stopping place in conjunction with good connections at the various junctions. The general principle of the arrangements on the Reading extension is a half-hourly train service in each direction, the trains running non-stop between London (Waterloo) and Staines. Additional services are provided at business hours. The trains are divided or made up at Ascot, one portion going to or coming from Reading, and the second portion going to or coming from Guildford *via* Aldershot.

A glance at the map might suggest that a circular service could have been run from Waterloo *via* Staines, Ascot, and Woking back to Waterloo, but such a scheme



***Above:* Lowering into position of the oil-cooled outdoor transformer for Ascot substation, the site of which is about 30 ft. below rail level**

***Left:* A general view of the reconstructed station at Ascot, showing in the middle background the new signalbox of the Southern Railway's latest standard pattern**

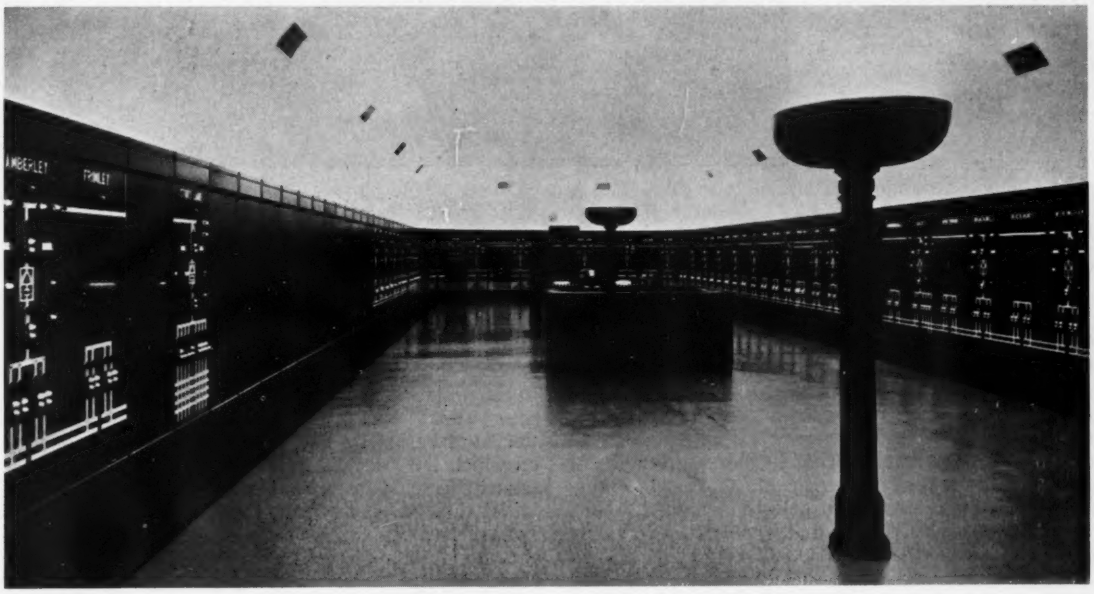
is not practicable, partly because of the already dense occupation of the four-track main line between Waterloo and Woking, and partly because of the appreciable local traffic between Camberley and Aldershot—both military centres—and between those areas and Guildford. Again, any north semi-circular working running *via* Staines and Ascot and terminating at Woking, would foul the paths of a number of trains at Woking station and approach. There is one train a day, the 5.37 p.m. ex-Waterloo on weekdays and the 1.37 p.m. on Saturdays which does run to Woking by the northern route, Staines—Ascot—Sturt Lane, but this is simply to maintain the facilities given by a previous steam service. A further advantage of the London—Ascot—Guildford route is that by one change at Guildford, passengers from the Ascot—Aldershot line can join the down Portsmouth fast trains.

The two down trains an hour leave Waterloo at 24 min. and 54 min. past the hour from 6.54 a.m. to 9.54 p.m., with late trains at 10.54 p.m. and 11.54 p.m., and an early morning train at 5.30 a.m. which replaces a previous steam train. At the weekday evening and Saturday lunch-time rush hours the service is increased to three trains an hour. In the up direction the half-hourly trains leave Reading at 29 min. and 59 min. past the hour from 9.29 a.m. to 10.59 p.m., with three trains an hour in the morning rush period from 6.21 a.m. to 8.49 a.m. In the up direction the trains leave Guildford at the hour and at 30 min. past the hour, join the Reading portion at Ascot and leave that station at 57 min. and 27 min. past the hour, and arrive at Waterloo at 42 min. and 12 min. past the hour. The 11.54 p.m. down train from Waterloo provides a theatre service every weekday.

Between Waterloo and Ascot the standard time for the 29 miles is 48 min.; to Reading, 43½ miles, 75 min. In the up direction the standard time from Reading is 73 min. and from Ascot 45 min. Over the 19 miles between Waterloo and Staines the non-stop times are 26 min. up and 28 min. down. On weekdays, 36 electric trains averaging 76 min. have replaced 20 steam trains averaging 87 min. between London and Reading, and in the reverse direction there are now 36 electric trains averaging 74 min. contrasted with 20 steam trains averaging 85 min. Even greater improvements have been made in the service accorded the Camberley line, which now has 69 services from London by the various routes compared with 53 previously, including 36 through electric trains taking 62 min. contrasted with only two through steam trains.

In general, the Sunday services correspond with those operated on weekdays, trains being run at half-hourly intervals, from Waterloo between 7.54 a.m. and 10.24 p.m., and from Reading between 7.59 a.m. and 10.29 p.m. All these trains have portions serving Camberley, Aldershot, and Guildford.

As with previous Southern Railway electrification extensions, the complete scheme for the conversion of the Reading lines was prepared under the direction of Mr. Alfred Raworth, the railway company's Chief Electrical Engineer.



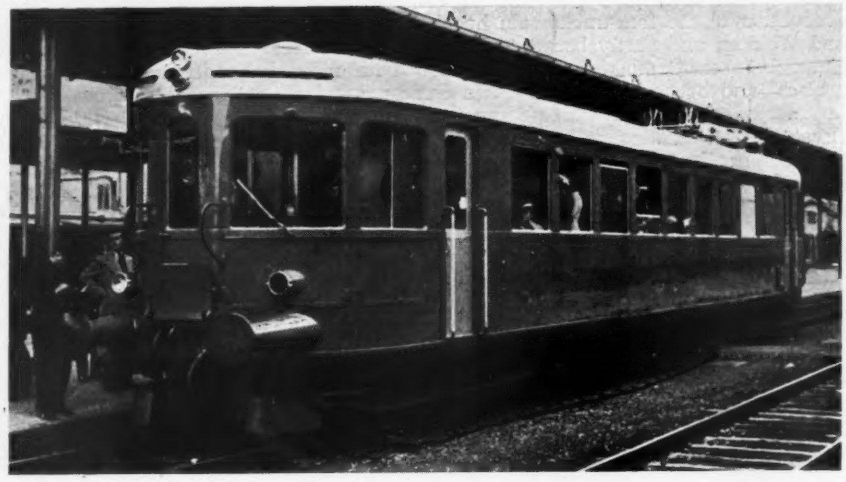
Interior of Woking control room showing on each side wall at the near-end the panels for the Reading extension substations and track-paralleling huts

Electrical Contractors

Asea Electric Limited : H.T. switchgear and supervisory control equipment.
British Insulated Cables Limited : L.T. cables and track bonding.
British Thomson-Houston Co. Ltd. : High speed circuit breakers.
Bruce, Peebles & Co. Ltd. : Mercury arc rectifier equipment.
Chloride Electrical Storage Co. Ltd. : Batteries for substations and control room.
English Electric Co. Ltd. : Electric train equipments.
W. T. Henley's Telegraph Works Co. Ltd. : Multi-core cables.
Pirelli-General Cable Works Limited : H.T. and pilot cables.
Westinghouse Brake & Signal Co. Ltd. : Motor-driven air compressors.
Taylor, Tunnicliff & Co. Ltd. : Conductor-rail insulators.
Pritchett & Gold & E.P.S. Co. Ltd. : Emergency batteries.
S. F. Bowser & Co. (London) Ltd. : Oil store equipment.
Siemens Electric Lamps & Supplies Limited : Lamps.

NEW ELECTRIC MOTOR-COACH SERVICE IN SWITZERLAND

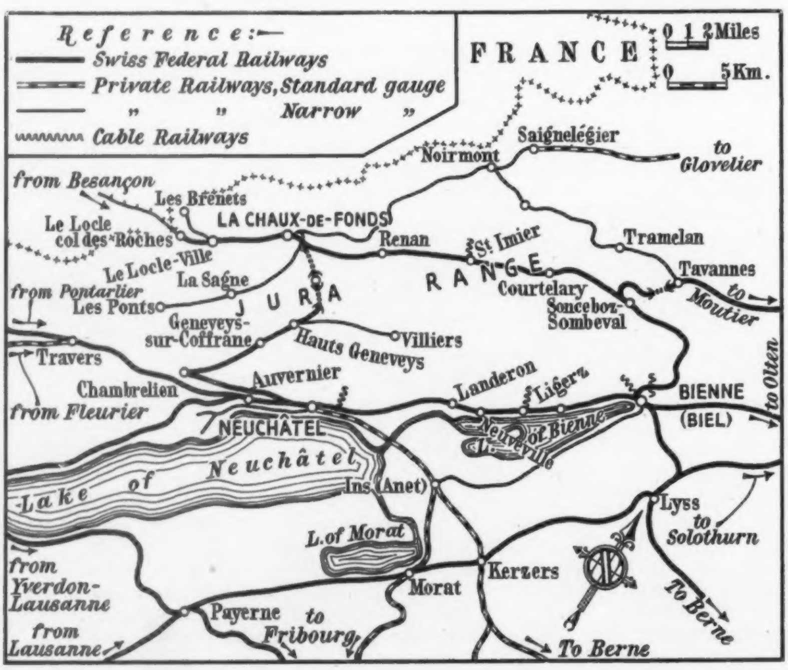
Caters for business service near French frontier



The Jura Arrow at La Chaux-de-Fonds

TO mark the inaugural runs of the new Flèche du Jura (Jura Arrow) electric motor-coach, two special trips and an official reception at La Chaux-de-Fonds were held on November 24, and the car went into regular service four days later. The map reproduced herewith shows the routes over which the Jura Arrow works. The whole of this district is famous as a watch-making centre, and the most important towns engaged in this industry and the production of accessories are Chaux-de-Fonds, Le Locle, and St. Imier. The Neuchâtel-Chaux-de-Fonds line has a ruling gradient of 2·7 per cent. (1 in 37) except through the Loges and Mont-Sagne tunnels (3,259 and 1,354 m. long respectively), and involves reversal at Chambrelien. On the Bienne—Chaux-de-Fonds—Le Locle line there are sections at 2·5 per cent. (1 in 40), but also many easier stretches, and fast running can be made for some distance, as curves are for the most part easy.

Electrification of the Neuchâtel—Le Locle line in 1931 and the Bienne—Chaux-de-Fonds line in 1934 brought about accelerations and improvements, but not to the extent desired by the population and particularly the business men of the district. The Federal Railways, on the other hand, did not feel justified in providing additional services, but duly gave consideration to the proposal, due to the initiative of M. Essig and his friends, that an organisation should be formed to acquire a lightweight railcar of the latest design for services on the two routes concerned, on which the Federal Railways would consequently undertake to provide faster and more frequent services. After initial difficulties, the co-operation of a number of public bodies, business firms, and associations was secured, and the Fondation de la Flèche du Jura was formed on March 15, 1937. This organisation has contributed 45 per cent. of the cost of the motor-coach, the Federal funds for works intended to relieve unemployment subscribed 33 per cent. and the remaining 22 per cent. was borne by the Federal Railways. Pending delivery of the actual



Map of lines in the Jura district showing routes served by the new electric motor-coach Jura Arrow, operating on the 15kV. 16⅔-cycle single-phase system

Flèche du Jura, the Federal Railways provided the additional services required by means of an ordinary motor-coach and control trailer. Altogether, the increased daily mileage on both routes amounts to about **400** train-km. (**250** train-miles).

The new motor-coach was delivered on October **28** last. It has an overall length of **22·6** m. (**74** ft.), tares **44** *tonnes*, and has a capacity of **71** passengers seated and **30** standing. The maximum speed is **110** km.p.h. (**68** m.p.h.), and the motor output on the one-hour rating is **620** h.p. Two trailers can be hauled, and the double Westinghouse brake is fitted in view of the severe gradients, although regenerative braking is also incorporated. The bogies have radially-guided axles on the SIG/VRL system, generally similar to those on the new Lötschberg twin unit Blue Arrow railcars described in the December **9** issue of this Supplement.

Externally, the car is painted light green, with orange lettering, and with its rounded ends has a not unpleasing appearance. Only third class seating is provided, in two compartments, and there is lavatory and postal accommodation. The seats are upholstered in artificial leather. The weight per seated passenger is **620** kg. (**1,365** lb.) as against **840** kg. (**1,825** lb.) for an express train of standard stock and **560** kg. (**1,235** lb.) for the streamlined three-car trains of the Swiss Federal Railways. The electrical equipment of the car was supplied by Oerlikon, and the body by the Swiss Locomotive & Machine Works at Winterthur.

Publications Received

Die Ortsfesten Anlagen Elektrischer Bahnen (The Fixed Equipment of Electric Railways). By Dr. Techn. Karl Sachs. Zurich: Orell Füssli. 7¾ in. × 10¾ in. 322 pp. 430 illustrations; 8 folding plates. Sw. Fr. 48 or RM. 29.—Just ten years ago was published an epoch-making volume on electric locomotive design, "Elektrische Vollbahnlokomotiven," which covered not only the mechanical and electrical equipments, but also three-phase, single-phase, and d.c. principles. In the intervening decade we have heard many a hope expressed that the author would undertake a similar work on the fixed equipment of electrified railways, and, at what seems a very long last, this volume has reached us. Although the publishers are not the same—Julius Springer of Berlin handling the first volume—the size, format, style, binding, and method of treatment are similar, so that the two books can be considered as parts of a single complete work, produced in the first class style always associated with Springer's Berlin house.

Energy supply and consumption of electrified railways are dealt with rather briefly in the first chapter. Scant attention is given to steam power stations, a little more to hydro-electric stations, and then the generating machinery of single-phase and three-phase energy is discussed. High-tension transmission at 50-66 kV., 80-110 kV., and 132 kV. forms the subject of the second chapter, but is given even less space, being allowed only seven pages. Passing to substation equipment, the author begins to spread himself, dealing with rotary and rectifier sets, and with the transformers and switchgear for single-phase, three-phase, and d.c. installations, and describing the mobile plants of the Italian, Swedish, and German State Railways, and giving brief but interesting particulars of the interconnection of single-phase and three-phase supply networks in such locations as the Hamburg suburban area, and in Switzerland and Norway.

By far the greater part of the book, 196 pages in all, is given up to current distribution equipment, but of this, third-rail systems get only half-a-dozen pages. After consideration of the various factors of voltage drop, analyses are made of the numerous conditions governing the mechanical design of the overhead structure, of the resistances of various materials and constructional details, of catenaries, hangers, and contact lines. Drawings and descriptions are given of a large number of systems used on Continental railways on open line and in tunnels, and sectionalising arrangements, as used on the single-phase lines of the Swiss Federal and former Austrian Federal Railways are described with the aid of several diagrams.

Throughout the book the author has avoided reference to English practice, and this is particularly regrettable in the sections on substation equipment and third rails. The great network of the Southern Railway's electrification entitles some of its equipment, especially the standard rectifier sets, the location and layout of the substations and track-paralleling huts, and their supervisory control, and the rail bonding, to be dealt with adequately in any major work on railway electrification. Moreover, the use of glass-bulb rectifiers for low-tension d.c. lines in England and in the Colonies is perhaps a stage ahead of that on Continental railways—as distinct from tramways—and the description of the Brown Boveri steel tank inverted rectifiers on the South African Railways is surely a little out of place when **85** per cent. of the inverted equipment on that system is of B.T.H. manufacture. Finally no discussion on high-tension d.c. can afford to neglect the work done by British contractors in such places as Brazil and Poland. Inclusions of such material could have been made easily without lengthening the book, by withdrawing the sections on trolley-bus equipments, signalling, and train heating, which are either too short to be of any use or are out of place in a book on electric railways. In reality, the book is one on the fixed equipment of a.c. railways, and the d.c. sections are in the nature of *obiter dicta*. Nevertheless, this book must surely take its place as a reference work on all forms of overhead construction, and a revised version in English would not come amiss.

Electrical Engineering Report.—The latest report of the Electrical Section of the Engineering Division of the Association of American Railroads has just come to hand. Its scope extends beyond the field of traction to all types of uses of electricity on railways. The most complete reports are those dealing with electrolysis, which includes a paper on stray current electrolysis in Australia, and leakage through the foundations of catenary supports; the standardisation of apparatus and materials, principally insulation, insulated cables, and conduit; protective devices and safety rules in electrified territory, including rules for the transfer of inflammable liquids and the prevention of sparks which may cause fire during the transfer; and specifications for track and third rail bonds, which was briefly abstracted in the issue of this Supplement for December **9**. This last report is a particularly interesting contribution, and contains a table giving details of the track rail bonds used on **17** electrified lines in North America, covering high, medium, and low tension d.c. and high tension a.c. electrifications. Non-traction reports include one on electric heating and welding, which is concerned mainly with the application of electric heat to the cleaning and drying of flood-damaged equipment, a subject which is of particular importance in the Middle West. A further report, on illumination, goes into the details of floodlighting in yards, and discusses the lighting systems and the characteristics of the projectors, the tower location, and the general procedure in designing a floodlighting installation; there is also a note on developments in incandescent lamps for general purposes.

NOTES AND NEWS

Electric Rack Railways.—A brochure containing some fine photographs and brief particulars of the vehicles for the Rigi, Pilatus, and Rochers de Naye rack railways in Switzerland, has been sent us by the Swiss Locomotive & Machine Works, of Winterthur, which firm built the mechanical portions for all 16 motor-coaches running on these lines.

Australian Electrical Equipment.—A total of 24 new 1,500-volt d.c. motor-coach equipments for the Sydney suburban electrified system has been ordered by the New South Wales Government Railways. The traction motors for this order are being made by the Australian General Electric Co. Ltd. to Metropolitan-Vickers designs, and parts of the control apparatus are being made at Metro-Vick's Trafford Park works.

Swedish Private Line Electrification.—The first of a series of nine electric passenger locomotives with a maximum capacity of 2,000 h.p. and suited to a top speed of 68 m.p.h., has just been delivered to the Trafikförvaltningen Göteborg-Dalarne-Gävle, for operation over the Gothenburg-Mellerud-Kornsjö line, now being converted to 15 kV. single-phase traction. The firms of Asea and Nydquist & Holm are building the locomotives. The traffic combine mentioned above includes the Bergslagen Railway, which owns the line from Gothenburg to Amal; thence to the Norwegian frontier at Kornsjö the route belongs to the Dalsland Railway.

Italian Electrification.—Dott. Ing. Marco Semenza informs us that the Milan-Gallarate-Varese line has not yet been actually converted from 650-volts to 3,000-volts d.c., as stated on p. 1029 of the issue of this Supplement for December 9. To the list of private electrified lines given on p. 1030 of that issue should be added the Piacenza-Bettola Railway, route length 33 km., standard gauge, 3,000-volts d.c. This line, projected by Dott. Ing. Semenza, was described in the issue of this Supplement for April 5, 1935. According to the latest accounts, it is expected that the electrification on the 3,000-volts d.c. system of the Milan-Chiasso section will be finished by the end of January.

French Electrification Notes.—Electrification of the line from Angoulême to Bordeaux is now completed, and early in 1939 all trains from Paris to Bordeaux and Hendaye, on the Spanish frontier, will be electrically hauled throughout. The French National Railways has also completed the electrification of the suburban extension of the line from Massy-Palaiseau to St. Rémy-le-Chevreuse, and since December 3 the Metro has been running trial services direct from Luxembourg (Paris) to St. Rémy.

The Chicago North Shore Line.—Another stage in the history of this line, the recent troubles of which were described in the issue of this Supplement for November 11, 1938, has been reached with towns' meetings and petitions by residents along the line. At a meeting in Chicago, 300 representatives from 25 areas heard railroad officials say they needed three million dollars to buy streamline equipment, and new trains, and pay taxes. A committee to ensure the continued operation of the North Shore line was set up.

The concern for the railroads' future is an outcome of the 52-day strike which was felt to have crippled business in the cities served. The line has had a pay roll aggregating $52,000,000 in the last 21 years, and has contributed much to the 178 per cent. growth in population in the area between Evanston and Waukegan since 1916.

Bernard J. Fallon, executive officer of the North Shore Line, and Albert A. Sprague, receiver, were among the speakers. Fallon said the cutting of basic fares by the Interstate Commerce Commission reduced the revenue from $7,967,000 in 1928 to $4,160,000 in 1937, although the number of passengers dropped only from 10,300,000 to 8,215,000. Competition from unregulated truckers using the highways also has cut into the freight receipts.

San Francisco Transport.—The new San Francisco-Oakland Bay bridge was opened to transport facilities at the beginning of the year. The electric railway over it is operated jointly by the Southern Pacific Railroad and the Key System.

Automatic Substation Saving.—An annual saving of $3,080 compared with a change-over installation cost of $2,356 has been obtained by the Utah-Idaho Central Railroad through installing automatic equipment at its Ogden substation, which feeds part of the company's 1,500-volt d.c. electrified line, used mainly by freight trains.

Dutch Railway Mishaps.—The recent wintry weather caused some disorganisation on certain of the electrified lines of the Netherlands Railways, owing to quantities of fine snow penetrating into the nose-suspended motors and into the control gear located below the underframes.

Leeds Underground Proposal.—A scheme for constructing 12½ miles of electrically-worked tube railways connecting the centre of Leeds with the suburbs has been under consideration. An expenditure of £6,250,000 has been mentioned. Greatly improved transport facilities for the citizens appear to be but a secondary object of the sponsors, who are putting the scheme forward as an air-raid shelter.

Cold Cost £105,000.—Lord Ashfield has stated that the Christmas cold spell cost the L.P.T.B. an extra £105,000, of which £55,000 represented the cost of special work which had to be done owing to frost and snow, and £50,000 loss of traffic. A feature of the activities at the train depots was the use of a fluid which has already proved effective in preventing aeroplane engines from freezing. This fluid was injected into the air pipes of a number of cars in an effort to prevent valves from freezing.

New Lötschberg Locomotives.—Two new 6,000 h.p. electric locomotives are at present under construction for the Berne—Lötschberg—Simplon Railway; the electric equipment is being supplied by the Sécheron works as general contractors and the mechanical portion by the Swiss Locomotive & Machine Works, Winterthur. The new units are to haul heavy express passenger and goods trains over the Lötschberg main line, and will be capable of handling a 600-*tonne* train at 90 km.p.h. (56 m.p.h.) on the level and at 60 km.p.h. (37 m.p.h.) on a 2·7 per cent. (1 in 37) gradient. The latter performance corresponds to a tractive effort of 18,000 kg. (39,600 lb.) at the drawbar and 24,000 kg. (52,800 lb.) at the wheel rims. The overall length is 20·26 m. (66½ ft.), and the wheel arrangement is 1 – Co+Co – 1; the end axles are of the Bissel type. The diameter of the driving-wheels is 1,350 mm. (53 in.). The locomotives are equipped with the Signum automatic train control apparatus and with a dead-man pedal, enabling them to be manned by a driver only.

Electric Railway Traction

Steam Freight Trains on Electrified Lines

CONSIDERABLE complication is introduced into the working of a frequent service of electric trains by the presence of steam-worked freight trains. In this country it is rarely practicable to operate the freight traffic by electric locomotives because of the concentrated form of the electrified areas, and in the case of the cross-London freight traffic the growth of the electric train services on the Southern Railway necessitated the construction of the Lewisham loops, so that most of the freight traffic from the northern lines could be re-routed *via* Blackfriars, Peckham Rye, and Lewisham to Hither Green, instead of over the Blackfriars-Metropolitan junction loop and the ex-S.E.C.R. main line, as formerly. These loops, now electrified, have also enabled fresh passenger services to be run. In Belgium, the heavy steam-worked freight traffic and through passenger trains led to the construction of what was almost an entirely new line when the Brussels-Antwerp section was electrified for interurban passenger traffic in 1935. Another area in England where a very heavy freight and mineral traffic, as well as a heavy main-line steam passenger service, complicates electric working is the North Tyneside district of the L.N.E.R. Either-way working over two of the four tracks between Newcastle (Central) and Manors has eased the position, but strict timekeeping is essential at more than one point east thereof, because of the peculiar layout of the various lines and the number of directions in which the mineral and empty trains run. For certain freight trains it was found advisable to change the marshalling point, although this involved longer hauls. However, the position was again ameliorated by further electrification—of the South Shields branch—which enabled the number of movements fouling the freight and main steam lines to be reduced considerably, and thus assisted punctuality.

L.P.T.B. Statistics

THE last annual report of the London Passenger Transport Board shows that for the year ending June 30, 1938, the 174 route (487 track) miles of railway owned were operated by 1,400 motor-coaches, 1,789 trailers, and 49 electric locomotives. The train-miles run over the Board's system amounted to 26,771,409, equivalent to 145,597,261 car-miles, but including mileages run by L.P.T.B. stock over other railways the aggregate figures were 32,415,661 and 175,935,517 respectively. The number of passengers originating on the Board's railway system was 487,749,023, or 13 per cent. of originating traffic on all forms of L.P.T.B. transport, but approximately another 90,000,000 passengers coming from other railways were carried, making a total of 578,000,000. The total amount of current used by trains, trolley-buses, and trams was 735,773,465 low-tension units, and the cost was £1,641,334 equivalent to 0·535d. per unit. Electric current for the running, lighting, and heating of the trains comprised £667,748 of this total. Current purchased from outside sources cost only £142,698; the remainder was supplied by the L.P.T.B. power stations at Lots Road, Neasden, and Greenwich. Maintenance of the rolling stock cost £489,371, equivalent to 0·67d. per car-mile. Among the improvements effected during the year under consideration was the introduction of nine-car trains instead of seven-car sets during rush hours on the Edgware—Kennington section. To avoid lengthening the platforms at the underground stations the two extra cars are reserved for use only at certain stations which have extremely heavy traffic, and the stopping of the trains is adjusted accordingly. Platforms have been lengthened at the surface stations from Golders Green to Burnt Oak, and at these the whole nine cars are available for picking up or setting down passengers. Southbound in the morning, after the train leaves Golders Green, the two rear cars are reserved for passengers to Tottenham Court Road only, and remain in the tunnel at other stations. Northbound in the evening the two rear cars are brought to the platforms at stations from Kennington to Leicester Square, and then remain in the tunnel at stations from there to Golders Green; the two front cars are therefore empty until Tottenham Court Road station is reached, but are available from there onwards. This operation has proved satisfactory, and the possibility of extending similar nine-car working to other sections is being considered.

Electrification and Track Layout

AMONG the advantages rarely credited to electrification works is the simplification of the permanent way layout—particularly in terminal areas carrying heavy traffic—which can be achieved when multiple-unit stock is used. This is due partly to the elimination of shunting movements by independent locomotives, and partly to the elimination of empty train movements and of the necessity of providing extensive berthing accommodation for passenger stock used only at rush hours. For example, the Southern Railway found it possible to eliminate 17 crossover roads, essential for steam working, at Brighton when the line to that town was electrified in 1932. Again, at Cannon Street terminus the whole of the approach track layout was greatly simplified when electrification was carried out. Such improvements are not confined to terminals. On open line between London Bridge and Bricklayers Arms junction there were in steam days two sets of three lines each, one set consisting of a down and two up lines, and the other of one up, one down, and one either-way lines, an arrangement which suited steam working, with its empty trains and light engines running between London Bridge and New Cross Gate. The reversible line was used according to the flow of traffic, but when the route was completely electrified and the number of up and down movements became virtually equal, it was possible to make a general improvement by having three up and three down lines. A more unusual problem, mentioned by Mr. S. W. Smart in his recent paper before the Bristol centre of the Institute of Transport, arose on the Southern Railway when the conversion of the West Croydon to Wimbledon line was under consideration. The steam passenger service was infrequent and the line single track, but with a number of sidings serving different factories. It was desired to run three electric passenger trains an hour in each direction, and at first it was proposed to double the line. Further investigation showed that it would be better to retain the existing single line, as such, for the electric passenger trains, and to link up the sidings to form an independent freight track, thus enabling the goods trains to be run and shunting carried on without upsetting the passenger service.

THE REEF MULTIPLE-UNIT STOCK

A description of the electrical equipment of the fast suburban and short-distance interurban vehicles, with automatic acceleration, for the 3,000-volt d.c. electrification in the Pretoria-Johannesburg area

By E. S. JOHNSON,
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U.S.A.

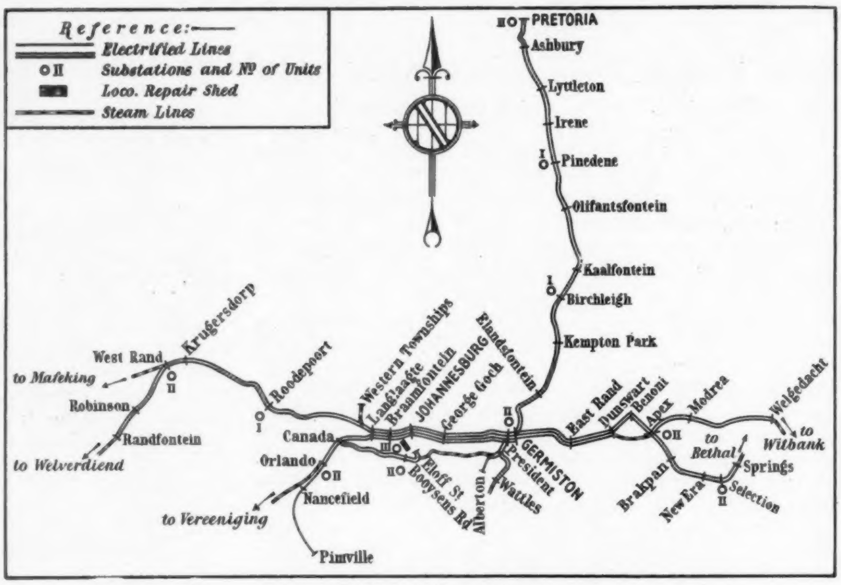


Fig. 1. Map of Reef electrified lines, showing number of tracks

EARLY in 1935 the electrification of the principal lines in the Reef area was authorised by the administration of the South African Railways and Harbours, in order to cope with the increasing traffic in the Johannesburg district while at the same time speeding up the schedules and eliminating the smoke nuisance. The conversion to the 3,000-volt d.c. system of 132 route-miles, equivalent to 402 track-miles, was sanctioned, and the scheme was completed by the opening to regular electric services of the last section—from Kempton Park to Pretoria—on November 7 last. Power is supplied through a dozen rectifier substations located as shown on the accompanying map. Coincident with electrification, a number of changes were made in the track alignment, and numerous level crossings were eliminated, on the Randfontein—Springs section, and, further, the Pretoria—Olifantsfontein division of the Germiston—Pretoria line has been double-tracked. Freight working also has been improved.

Rolling Stock

The original contracts in the rolling stock section comprised, as far as electrical apparatus was concerned, 72 four-motor 1,500-3,000-volt multiple-unit equipments with one driving position; 32 trailer equipments with one driving position; and 128 non-driving trailer equipments. Subsequent contracts increased these totals to equipment for 119 motor-coaches, 80 driving trailers, and 235 non-driving trailers. All these equipments were not installed in new

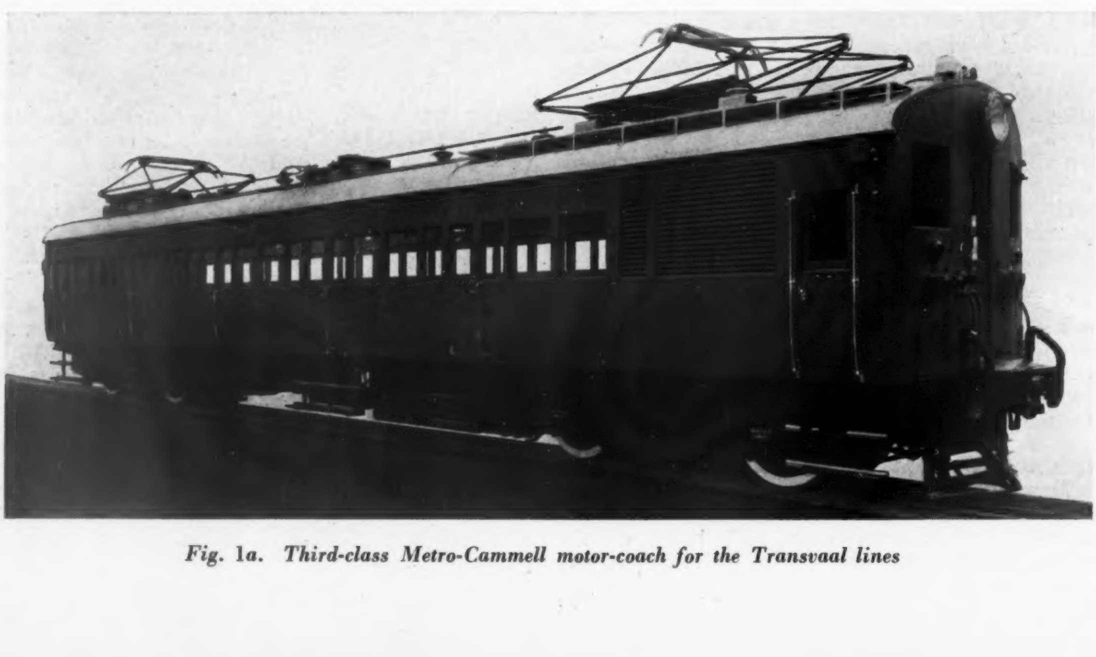


Fig. 1a. Third-class Metro-Cammell motor-coach for the Transvaal lines

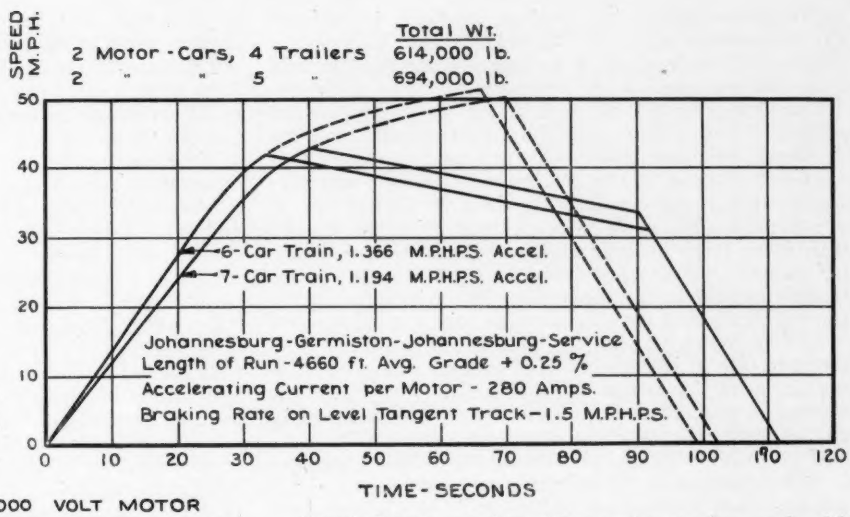
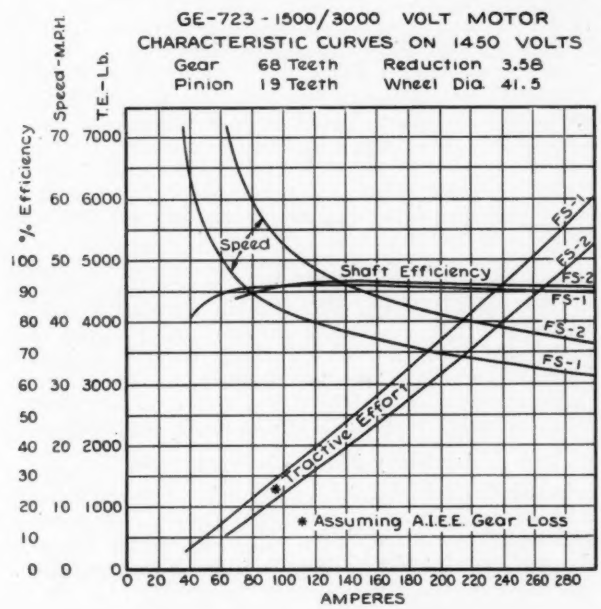


Fig. 2 (right). Typical speed-time curves of six-car and seven-car trains over a start-to-stop distance of 0·882 miles

Fig. 3 (below). Characteristic curves of American General Electric traction motor as used on the Reef motor-coaches



stock, the trailers being rebuilt from steam stock by the South African Railways. The motor coaches and certain driving trailers, generally of steel construction, were ordered from the Metropolitan-Cammell Carriage & Wagon Co. Ltd. and the Birmingham Railway Carriage & Wagon Co. Ltd. The Metro-Cammell cars, briefly described in the issue of this Supplement for August 19, 1938, have 74 to 99 seats on a tare weight of 56¾ tons. Certain motor-coaches have first class accommodation and the others third class, and in both types the seats are arranged in open saloons. The bogies have a wheelbase of 8 ft. 6 in. and are pitched at 41 ft. centres. Timken roller bearing axleboxes are used.

Requirements of the Electrical Equipment

The motive power equipment, in order to meet the varying needs of high-speed local and express suburban service, had to be characterised by reliability, simplicity, flexibility, high balancing speed, and the design and installation of all parts to facilitate inspection, removal, and replacement. The contracts for all the equipment were placed with the South African General Electric Co. Ltd., and manufacture was undertaken by the General Electric Company of America.

A typical train consists of two motor-coaches, each with four motors, and four trailers, and the total weight is made up approximately as given in Table I. The specification required such a train to make an average speed of 30 m.p.h. start-to-stop on a one-mile straight and level track with a braking rate of 1·5 m.p.h.p.s. and a tension of 2,900/2 volts at the motors.

Typical of the operating requirements is the service between Johannesburg and Germiston, a distance of 8·82 miles, wherein there are nine intermediate stops, making ten runs with an average length of run of 0·882 mile. Based on a run in each direction, the equivalent average grade is estimated at +0·25 per cent. Typical speed-time curves of this run with six-car and seven-car trains are shown by curves, Fig. 2. There are indicated also the rate of acceleration, weight of train and the accelerating current per motor. Normally there is an appreciable leeway in the schedule running time (of 113·5 sec.) as shown by the amount of coasting. The balancing speed of a six-coach train on level tangent track with 2,900/2 volts applied to the motors, and with shunted field, is 63 m.p.h. Maximum permissible speed based on A.I.E.E. standards without injury to the motors is 72 m.p.h.

Based on BSS. No. 173 standards for traction motors having Class B insulation, the GE-723-1,500/3,000-volt motor used has the following ratings:—

	Amp.	H.p. at shaft	Volts	Field strength	Cu. ft. of air per min. (approx.)	Temp. rise by resistance
One-hour (nominal)	168	315	1,500	Shunted	1,040	120° C.
Continuous ..	145	262	1,450	Shunted	1,045	105° C.
Continuous ..	140	251	1,450	Full	885	105° C.

The characteristic curves of this motor, and the tractive efforts with wheels of 41½ in. diameter are given in Fig. 3. The motor is ventilated by a self-contained fan mounted

TABLE I

Motor-coaches—	
Coach body only, but including load (passengers)	76,600 lb.
2 bogie trucks	36,000 lb.
4 GE-723 motors	23,680 lb.
Control and miscellaneous	11,400 lb.
Total weight per coach	147,680 lb.
Total weight two motor-coaches	295,360 lb.
Total weight four trailer coaches	320,000 lb.
Total weight of six-coach train, loaded and equipped	615,360 lb.

on the pinion end of the armature, air being taken in at the commutator end and drawn over and through the longitudinal ducts of the armature and around the field coils, and exhausted at the pinion end.

This brings up the question of the air supply for the cooling of the motors, and the motor-generator set for supplying auxiliary power. Experience has shown that 3,000-volt traction motors will be more reliable and successful when supplied with fairly clean ventilating air. It was therefore decided to take air through louvres in each side of the coach at points opposite the high-tension control compartment and just above the window ledge. Investigation has shown air above the window ledge along the side of a car when running contains only a small amount of dirt as compared with the air along the lower part of the car body in the trucks. The general arrangement of the air ventilation system adopted is shown by Fig. 5. A number of equipments have been in service since the early part of 1937, and inspection shows the motors to be practically free from dirt and in excellent condition. Important in this connection is the reduction in brush wear and the freedom from the sticking of brushes in the holders as a result of the elimination of dirt.

The frame of the motor is of the standard box type with nose suspension, and is practically cubical because of the space limitations of the 3 ft. 6 in. track gauge. Openings are provided at the top and bottom at the commutator end for inspection and renewal of the brushes. The armature bearings are of the cylindrical roller type, with special tolerances and clearance for railway service; they are grease-lubricated. The axle-bearing linings are of bronze with $\frac{1}{16}$-in. layer of babbitt at the wearing surface. They are of the oil-and-waste lubricated type with auxiliary wells provided for gauging and replenishing of the oil supply.

There are longitudinal ventilating ducts through the core of the armature. The construction is such that the shaft may be replaced in the assembled armature without disturbing the windings or commutator. The armature coils are of rectangular wire, with felted asbestos and mica tape used as insulation. The process of insulating and forming requires many operations and baking periods to successfully meet the severe service requirements. Five baking periods were used during the manufacture, varying from 8 to 24 hr. each. After completion, each armature is both statically and dynamically balanced, and an armature can be rebalanced at any time.

The commutator is 17-in. in diameter, and the segments have a wearing depth of 0·75 in. Successful operation of high-voltage traction motors demands that the commutator be so constructed that it permanently retains its original shape, and to ensure this requires close working limits and the highest technique and skill in assembly.

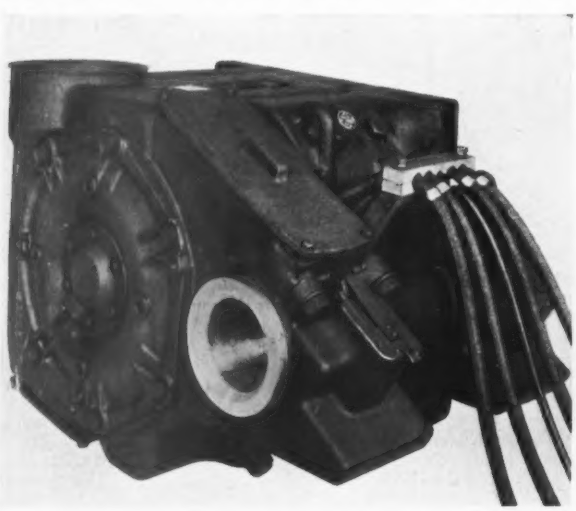
The exciting field coils are flat wound with strip copper, and have asbestos paper insulation between turns; the connections between the decks and the terminals are silver soldered. Spool flanges are used to support the coils in place in the frame and protect the insulation. It is very important that the coils remain tight after being assembled in the frame. This is accomplished by assembling the coils loosely in the frame, then heating them electrically and afterwards drawing the pole pieces down in place, securely clamping the coils. The manufacture and insulation of the commutating field coils is similar to that of the exciting field coils, except that the strip copper is edgewise wound. Both the exciting and commutating field coils are connected on the ground or negative side of the armature. Each motor is provided with four brush-holders, adjustable radially, with one brush per holder. The brush-holders have steel clockspring adjustable pressure fingers, constructed to maintain a central location.

Since two motors are permanently connected in series, only one inductive shunt is required for each pair of motors. These shunts are constructed and insulated in the same general manner as the exciting field coils of the traction motors.

The gear and pinion are of standard G.E. grade M, the gear being of the non-resonant solid type. The width of the tooth face is $4\frac{1}{2}$ in., and the teeth are proportioned in accordance with the A.E.R.A. standards for long and short addendum gearing. The gear cover is malleable iron, designed to ensure minimum leakage of the gear lubricant and constructed so that the seals around the armature shaft and the axle can be readily renewed.

Auxiliary Motor-Generator Set

Power for the operation of the exhauster, compressor, control, and lights is provided by a two-unit two-bearing motor-generator set consisting of a 3,000-volt two-pole d.c. motor and 11 kW., six-pole, 110-volt d.c. generator.



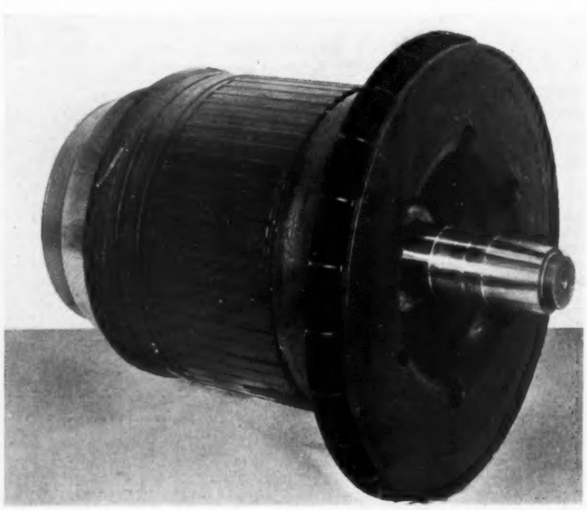
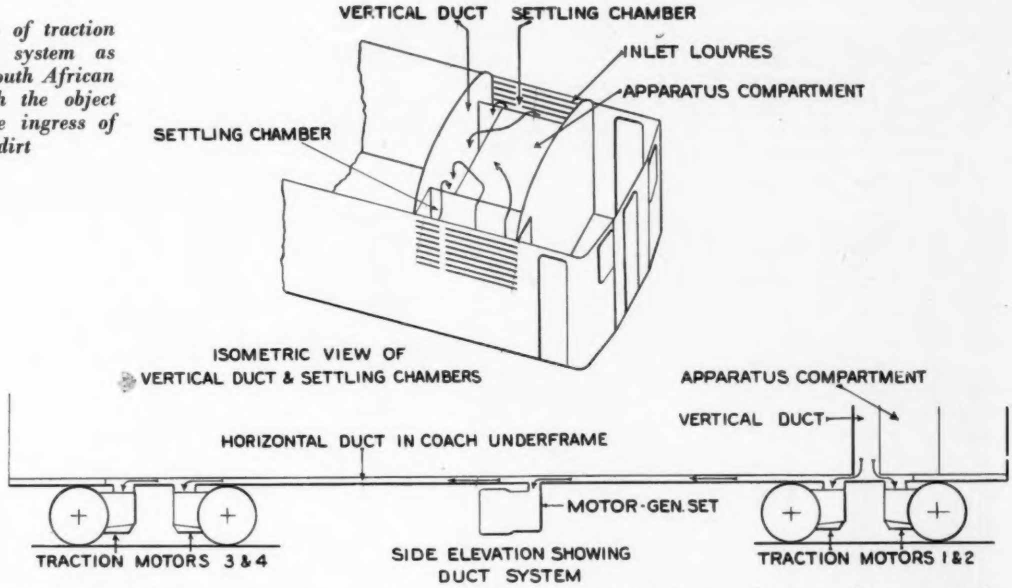


Fig. 4. Two views of a 315-h.p. nose-suspended traction motor. On the left is a view of the commutator end, and on the right is a pinion-end view of the armature and fan assembly

Fig. 5. Diagram of traction motor ventilating system as adopted for the South African motor-coaches with the object of eliminating the ingress of dust and dirt



In addition to supplying auxiliary power for a motor-coach, each motor-generator set has capacity for furnishing power for lights for two trailers and for the control for the operation of a nine-car train.

The frame of the set is of one-piece fabricated cylindrical construction. The two armatures are mounted on a single shaft with the commutators adjacent, thus giving access for inspection through a single opening on each side of the frame. An interlaced barrier between the ends of the two commutators ensures adequate separation of the 3,000- and 110-volt power to secure trouble-free operation. The set is suspended under the car body by rubber-cushioned bolts to prevent the transmission of any noise or vibration to the car body, and is self-ventilated by a fan mounted at the back end of the motor. Cooling air is taken from the duct system which ventilates the traction motors, and enters at the low voltage end. It is then drawn through the set by the fan and exhausted at the opposite end. A sponge rubber gasket between the car duct and the air inlet to the set ensures a tight joint and eliminates the transfer of noise or vibration to the car body. An inspection of the many sets now in operation shows that practically no dirt or dust of any type or kind enters the machine.

Constant voltage for the auxiliaries under all operating conditions is provided by a voltage regulator controlling the 110-volt generator. The combination of the generator design and voltage regulator permits an output of 11 kW. at 110 volts with a contact wire potential of 2,000 volts down to no-load with a contact wire potential of 3,300 volts. Good car lighting is thus provided under all operating conditions.

The generator voltage regulator is a comparatively recent development, intended specially for use with railway equipment. It has been widely used for the past four or five years on diesel-powered high-speed trains and locomotives. It has a dynamic floating armature giving rapid control of the voltage over a wide range of generator speed and load. It will hold the voltage within plus or minus 3 per cent. of 110 volts over the working range.

Multiple-Unit Control Equipment

The control for the motor-coaches is the General Electric Company's well-known PCM type, in which the main line contactors (breakers), the contactors for changing the motors and resistor connections from series to parallel, and the field shunting switches are electrically-controlled and air-operated; the contactors for cutting out the accelerating resistor steps are cam-operated by an electro-pneumatic mechanism. All the duty of opening and rupturing the

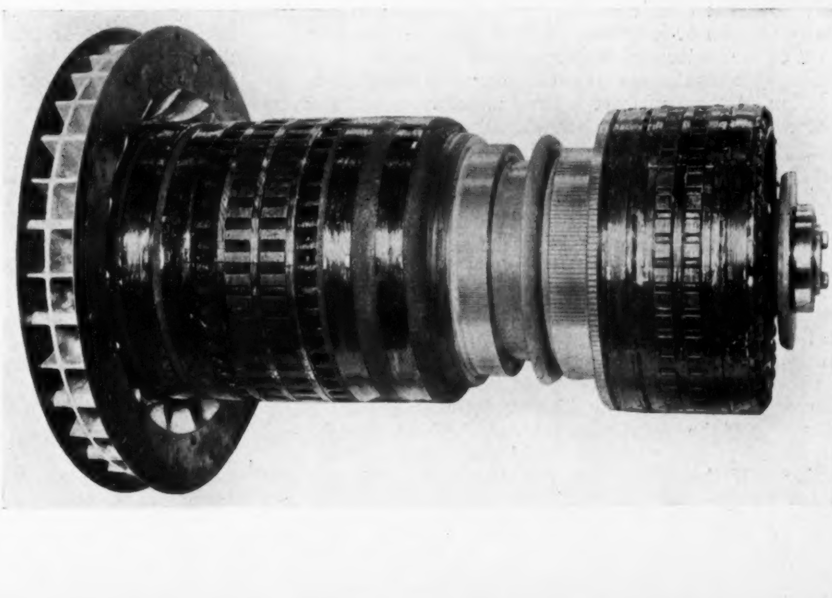
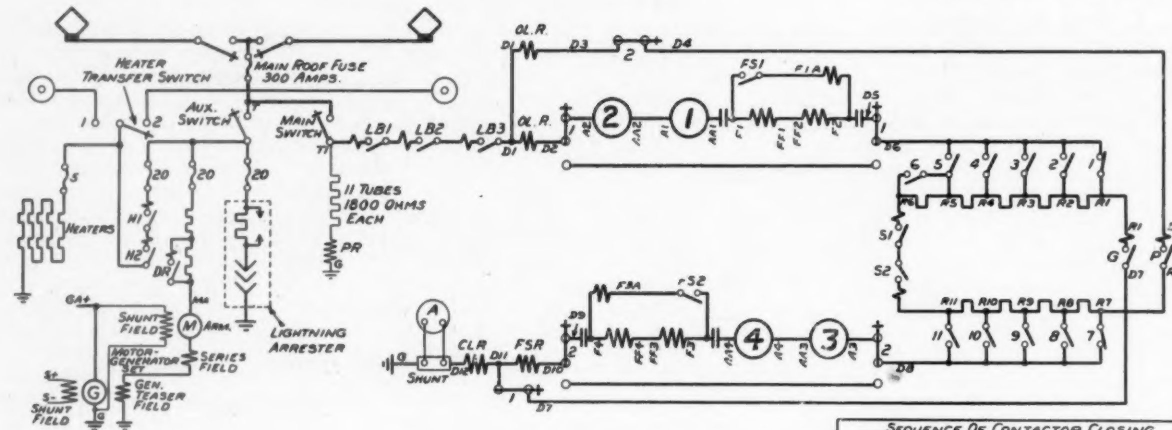


Fig. 6. Generator end view of the wound revolving armatures of the 3,000/110-volt d.c. auxiliary motor-generator set. The low tension generator is controlled by a voltage regulator



		SEQUENCE OF CONTACTOR CLOSING																			
POINTS		LINE BREAKER			MOTOR CONTROLLER											CONTACTORS					
		LB1	LB2	LB3	1	2	3	4	5	6	7	8	9	10	11	P	S1	S2	G	FS1	FS2
SERIES	OFF				●						●										
	1 (Sw.)	●	●	●	●						●						●	●			
	2	●	●	●	●	●				●	●						●	●			
	3	●	●	●		●				●	●	●					●	●			
	4	●	●	●		●				●		●	●				●	●			
	5	●	●	●		●	●			●			●				●	●			
	6	●	●	●			●	●		●			●				●	●			
	7	●	●	●				●		●			●	●			●	●			
	8	●	●	●				●		●				●	●		●	●			
	9	●	●	●				●	●	●					●		●	●			
	9A	●	●	●					●	●					●		●	●			
TRANSITION		●	●	●					●	●					●	●	●	●	●		
PARALLEL	10	●	●	●					●	●					●	●			●		
	11	●	●	●				●	●	●					●	●			●		
	12	●	●	●				●		●				●	●	●			●		
	13	●	●	●				●		●			●	●		●			●		
	14	●	●	●			●	●		●			●			●			●		
	15	●	●	●		●	●			●			●			●			●		
	16	●	●	●		●				●		●	●			●			●		
	17	●	●	●		●				●	●	●				●			●		
	18	●	●	●	●	●				●	●					●			●		
	18A	●	●	●	●						●					●			●		
	19	●	●	●	●						●					●			●	●	●

Fig. 7. Schematic diagram of main and auxiliary circuits, and contactor sequence diagram, of the American General Electric Company's P.C.M. control as fitted to the 3,000-volt d.c. multiple-unit car equipment on the latest electric trains of the South African Railways, used on the Reef and Natal sections. This particular application embodies 19 notches from starting up to the final step with shunted motor fields in full series-parallel connection. The figures 1, 2, 3, and 4 refer to the traction-motors on one motor-coach

motor circuits is imposed on the line breakers and series-parallel contactors which are provided with highly effective arc chutes. Five of these contactors are connected in series at all times and open to interrupt the power to the car, thus providing an ample margin of safety as two contactors in series have capacity for opening the power circuit. During normal operation, overload, or short circuits, all five contactors are opened simultaneously. As a further protection against possible damage to the equipment an enclosed fuse of very high rupturing capacity is provided. This fuse is mounted on the roof of the car.

The electro-pneumatic controller which functions to cut out the sections of the accelerating resistors in the proper order, is so arranged that the cam-operated contactors act only to short circuit resistor sections, thus requiring no blow-out coils or large arc chutes. By a unique arrangement of the motor and resistor circuits during series acceleration, the contactors cut out the resistance steps by rotation of the camshaft in one direction, and after the motors and resistors are transferred to the parallel connection the camshaft movement is reversed to again cut out the same resistors in reverse sequence by turning back to its original position. The arrangement thus obtains a large number of steps with a relatively small number of contactors and resistors. Eighteen steps are provided, giving quite small current variations from step to step, resulting in smooth acceleration. One additional step is provided by shunting the motor fields after the motors are in the full series-parallel connection, for which electric-pneumatic contactors with arc chutes are used.

The main and auxiliary 3,000-volt power circuits are shown by Fig. 7, the auxiliary 3,000-volt circuits being the motor of the motor-generator set, the heaters, lightning arresters, and potential relay, with the necessary fuse protection. If the power fails the motor circuit is at once opened by operation of the potential relay. However, if the master controller handle has been held in the power position until power is restored, the complete sequence is obtained to the controller position.

The master controller is simple, and compact, and has comparatively few parts. The fingers are interchangeable and are of a special design to ensure alignment and minimum wear. The contacts are easily replaceable. All of the motors of a train are controlled by one master controller, which is mounted in the operator's compartment at one end of each motor-coach and in each driving trailer. The master controller is equipped with a dead-man handle which is operative when the reverse handle is in either the forward or reverse position. The master controller provides for either automatic or manual acceleration in both the series or parallel connection of the motors. If the main control handle is released other than in the off position, the main contactors are automatically opened, interrupting the power supply to the motors, and a vent valve is also opened, which, through a vacuum relay valve, causes an emergency brake application.

There are five positions of the main control handle; off, switching, series, parallel, and shunted fields in either forward or reverse positions. In the switching position the line contactors, motors, and accelerating resistors are connected in series in the circuit. Moving the master controller from the switching to the series position automatically accelerates a train to the full series connections of the motors. For manual operation the handle is moved momentarily from the switching to the series position, and then back to the switching position. Similarly, when motors are in the parallel connection, the handle is moved from the switching position to the parallel position and then back again. The accelerating current can in this way be controlled. For complete automatic acceleration to the full

shunted connection of the motors, the controller can be set at once in the shunted field position. The transition from series to parallel connections is of the bridge type, which maintains full accelerating torque on the motors during the transition period and thus secures smooth acceleration.

High-Tension Control Group

All the 3,000-volt control is housed in a steel compartment located just behind the driver. Access to this equipment is obtained through a door in the driving compartment. To ensure safety for the inspection and maintenance of the 3,000-volt control apparatus, this door is so interlocked by a manually-operated three-way air valve controlling the raising and lowering of the pantograph, that the air supply is exhausted and the pantograph lowered before the door can be opened, and the pantograph cannot be raised until the door is again closed and the three-way valve thrown so that air can be supplied to the pantograph air cylinder.

All the apparatus is so arranged as to be easily accessible for inspection and maintenance. The high-tension compartment is totally enclosed in such a way as practically to eliminate the entrance of dust and dirt, and thus the apparatus, particularly the insulation, remains clean and is easily maintained. The high-tension control group is built as a unit on a welded steel framework, rigidly cross-braced for supporting the 3,000-volt apparatus. The whole group is completely assembled, wired, and tested as a unit. It is enclosed in a compartment built as a part of the motor-coach and arranged for ready removal merely by disconnecting the holding-down bolts and out-going cables.

Hook-operated isolating switches, having porcelain insulators, are provided for isolating the main motor circuit and auxiliaries. Totally-enclosed 3,000-volt fuses are used for protection of the motor of the motor-generator set, aluminium cell lightning arresters and the car-heater circuits. These fuses are of a new design, specially developed for this application. Previously many attempts had been made to develop a simple 3,000-volt totally-enclosed fuse for the protection of the auxiliaries of motor-coach and locomotive equipments, that would be blown without emitting a flame and still be reliable, so that it could be located in a restricted space. The problem was solved by using a special arrangement of the fuse in the

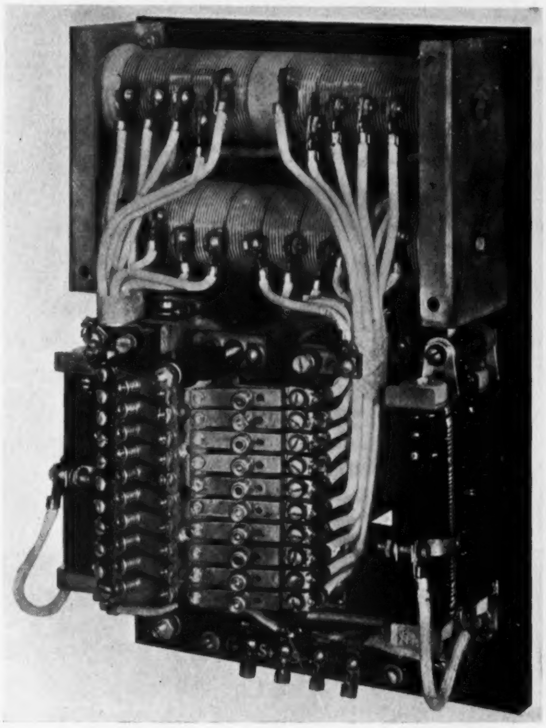
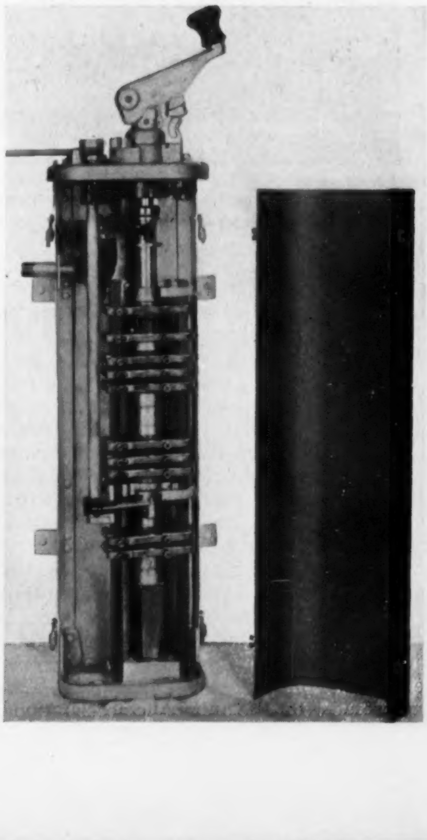
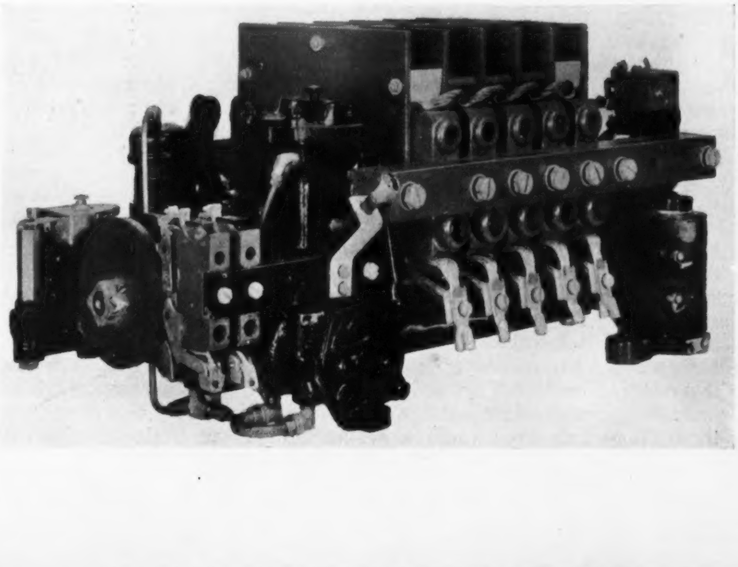


Fig. 8 (top right). The assembly of the voltage control relay, weighing 36 lb.

Fig. 9a (below). Cam-operated pneumatic controller as used on the Reef stock ; its weight is 168 lb.

Fig. 9b (right). American General Electric master controller and cover, weighing 43 lb.





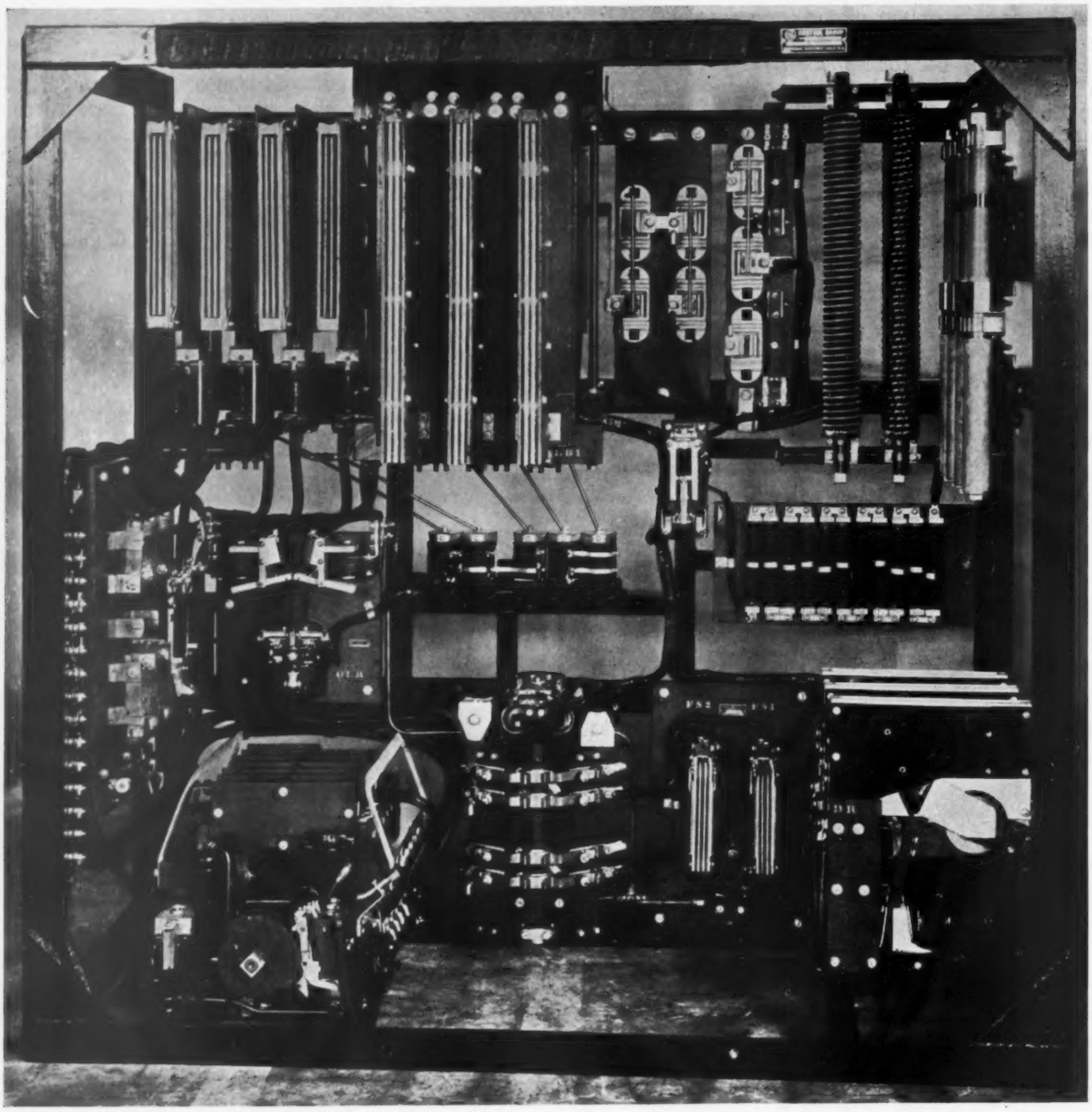


*Fig. 10. American General Electric high-tension control group as installed in the motor-coaches of the Reef electrified lines. The weight of the group shown is **1,623** lb.*

holder with a steel explosion chamber, which is that part of the fuse holder extending below the lower supporting clips. Auxiliary contactors are used for controlling the heater circuit and short-circuiting the starting resistance of the motor of the motor-generator set. These contactors are universally used in connection with miscellaneous 3,000-volt applications on coaches and locomotives and in connection with 3,000-volt JR high-speed breakers.

The reverser is of the electro-pneumatically operated drum type. Complete electrical interlocking is provided so that the reverser cannot be thrown from one position to the other under load and so that power cannot be applied to the motors unless the reverser is completely thrown to the position called for by the master controller. The overload relay has two series operating coils which are connected into the main motor circuits in such a way as to provide the same degree of overload protection for both the series and parallel connections of the motors. The overload protection is adjustable. The accelerating relay provides for the automatic acceleration by the cutting out of the resistors step by step, transfer to the series-parallel connection and again cutting out resistances, and then shunting of the motors. The degree of progression is determined by the position of the master controller. The inductive shunts for the shunting of the main motors and the aluminium cell lightning arresters are mounted in the high-tension compartment on the wall to the right of the entrance door, but apart from the high-tension group.

Lightning Protection

Lightning in South Africa is claimed to be more severe than in any other place in the world. The South African Railways have previously experienced great damage by lightning, to the electric locomotives, contact wires, and substation equipment on their Natal electrification. For this reason special precautions were taken to secure the best possible protection for these motor coaches. The aluminium-cell lightning arrester chosen for this protection has been uniformly successful in protecting equipment

against damage due to lightning, and the adoption of these arresters has been fully justified by the record of no damage due to lightning on those cars which have been in operation since the early part of 1937 or on any of the later vehicles.

Pantographs

Each motor-coach has two pantographs which are air raised and spring-gravity lowered. The working range from minimum to maximum height is 7 ft. 6⅝ in., and the length of contact working strip is 3 ft. 7⅞ in. The arrangement of the pressure springs is such that practically a constant pressure is exerted against the contact wire, irrespective of the height at which the skates are worked, and the balance is such that the skates easily follow the variation in the height of the contact wire with movement of the train. The pressure on the contact wire can be adjusted at any point between 25 and 30 lb. There are two contact shoes with independent flexibility and these are arranged so the contact strips always remain flat against the contact wire irrespective of the speed or the direction of movement, and thus ensure sparkless collection of the current.

The contact strips are of half-hard copper bar, formed with a radius on the outer side to protect the contact wire. The wearing strips are held in place by flat-head machine screws with hexagonal nuts and lock washers and are easily renewable. The end horns are of aluminium alloy and have a drop of 12 in. The curvature of the horn is such that the siding wires or crossing wires will be picked up smoothly. The upper and lower frames of the pantographs are of high-carbon seamless cold-drawn steel tubing, with cross bracing, and with high-grade malleable iron fittings, so as to obtain as light working parts as possible, but at the same time with necessary stability for successful operation. The main shaft bearings are self-aligning roller type, but those at the top, and where the upper and lower frames connect, are of the pin and clevis type with hardened steel bushings and pins with Alemite grease fittings. The jack-shaft bearings are of bronze with Alemite fittings. The whole arrangement of the bearings and alignment is such as to ensure freedom from excessive friction, even though some parts may be somewhat out of line due to weaving of the supporting roof.

Flexible shunts of sufficient capacity to ensure long life are used at all joints and bearing points so as to permit only a very small amount of current to pass through the bearings. The pantograph base is of angle iron, of rigid construction to prevent any excessive lateral or longitudinal oscillation of the movable frame. The insulated air connection to the pantograph air cylinder is a porcelain tube flexibly mounted, which arrangement has proved far more reliable and efficient than the rubber hose formerly used. Copper tubing mounted on insulators on the roof is used for the bus line between the pantographs, and is considered preferable to cable, which has generally been used in the past; flexible connections are used between the tubing and the pantographs. Copper tubing will remain straight, and even after being in service for some time will present a good appearance. Hook-operated disconnecting switches, mounted on the roof, are used so that either pantograph can be isolated by opening the switch with a pole.

Accelerating Resistors

The edge-wise wound type resistors are of rolled, non-corrodible alloy of unusually high specific resistance, and are practically unbreakable. Because of the special alloy used and the type of construction, an unusually large thermal capacity is obtained with minimum weight and

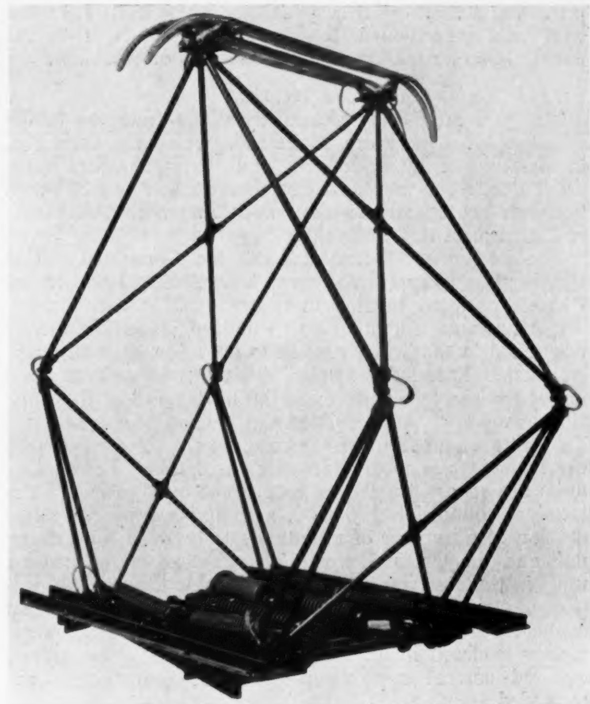


Fig. 11. Light-weight double-shoe pantograph with copper wearing strips and end horns of aluminium alloy

size. Each resistor is individually insulated and the group then insulated from ground. The resistors are mounted neatly in a group below the floor of the motor-coach.

Exhausters

The type CP-230 exhauster for the vacuum brakes is of the reciprocating type, and of the same general construction, except for the valves, as the compressor normally used for air brakes. It has horizontal duplex cylinders with single-acting trunk-type pistons; the cylinder diameter is 5¾ in. and the stroke 7 in.

All bearings are lubricated from one source, namely, the crank chamber of the exhauster frame. Oil is carried from the bottom of the chamber by the gear and delivered to an oil distributor attached to the frame, from which it is conveyed to the different bearings by means of channels formed in the distributor. There is one cylinder head and valve which serves both cylinders; these are specially designed for vacuum operation to obtain maximum freedom of air flow with minimum port clearance. There are three inner valves and three discharge valves of conventional type for each cylinder. These valves are held in place by keepers or bridges. The ends of the valves never leave the seat on the cylinder head, thus providing very silent operation.

The exhauster is driven by a series-wound 110-volts motor through gearing with accurately cut herring-bone teeth of liberal size. It has capacity sufficient to produce a 20-in. vacuum in a 12-cu. ft. container in 10 sec. with a constant link to atmosphere through a $\frac{3}{16}$-in. diameter hole under conditions at sea level. The motor is arranged to operate at two speeds giving normally an exhauster speed of 750 r.p.m., but for quick release of the brakes, is speeded up to 1,500 r.p.m. when the brakes are being released. The exhauster is supported under the car body by means of three suspension sockets cast integrally with the exhauster frame which secure the suspension bolts,

providing a three-point suspension. These bolts are fitted with rubber-cushioned bushings, so designed that the rubber is under tension, for the damping of vibration.

Car Heating

The cars are heated electrically direct from the **3,000**-volt supply. There are **13** heaters per coach, connected in series. On motor-coaches and driving trailers there are a dozen **800**-watt cross-seat heaters and one **865**-watt vestibule heater, and on the non-driving trailers **13** cross-seat heaters of **800** watts each.

The heaters were furnished by the Consolidated Car Heating Company Inc., Albany, New York. Two General Electric enclosed heating units are used in each heater. These units are mounted on secondary insulation and so positioned in the heater case as to provide ample air space between and around the units. This ensures uniform heating of the air passing through the heater and at the same time prevents the possibility of the units overheating. The bottom and front of the case are provided with sufficient openings to ensure adequate circulation. The heating units are so constructed as to prevent overheating of the terminal connections. This is accomplished by the introduction of a number of radiating fins between the heating unit and the terminal post. The location of the heating units in the case was arranged to provide the greatest possible electrical creepage along the connecting wires. When connected and ready for service, the terminals are completely enclosed in an insulation sleeve and there are no exposed current carrying parts. The heater cases are grounded.

The temperature of a motor-coach is controlled by a thermostat mounted on the wall near the centre of the passenger compartment. The thermostat, through an auxiliary relay, controls the temperature of the coach by the closing and opening of the main **3,000**-volt heater circuit through a contactor mounted in the high-tension compartment of the motor-coach. The contactor controls the main heater circuit, thus also controlling the heat supply to the associated trailers. The main circuit for supplying heat to the motor-coach and its trailers is protected by an enclosed fuse mounted in the high-tension compartment in the motor-coach. The heater control circuit to the motor-coach and to each trailer is individually protected by an enclosed fuse, the fuse for the motor-coach circuit being mounted in the high-tension compartment group and those for the trailers being mounted in boxes carried under the coach bodies. The covers of the fuse boxes on the trailers are provided with an electrical interlock so that when the cover is opened the heater-supply contactor in

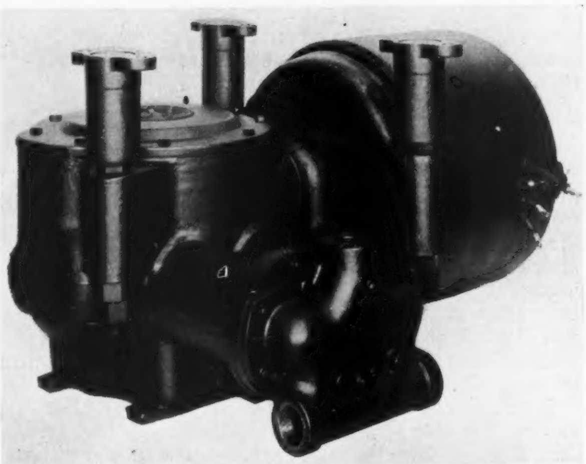


Fig. 12. *General Electric* **110**-*volt reciprocating exhauster set, viewed from the exhauster end*

the high-tension compartment of the motor-coach is opened and cannot again be closed until the cover of the fuse box is closed. Heater power to the trailer is provided by a **3,000**-volt bus line from the motor-coach, carried on top of the coaches with couplers and jumpers between. The coupler sockets are provided with an electric interlock operated by the cover, arranged so that the contactor in the high-tension compartment cannot be closed except when the cover of the coupler is closed or is in the position it assumes with the coupler plug in position. There is also in the high-tension compartment a single-pole, single-throw heater bus line selector switch permitting heater power to be fed in only one direction from the motor-coach at a time, either from the rear or the front end. These various features ensure safety to the trainmen when train make-ups are being changed, and to the travelling public.

On account of the very dry climate on the Reef, and unsatisfactory experience with wood insulation, all insulating bases and parts when not made of porcelain are of moulded compound or other suitable fabric insulating material. The box for housing the main roof fuse, the supports for the sides of the arc chute of the main line switches, and the motor cleats are exceptions and are of specially-treated wood.

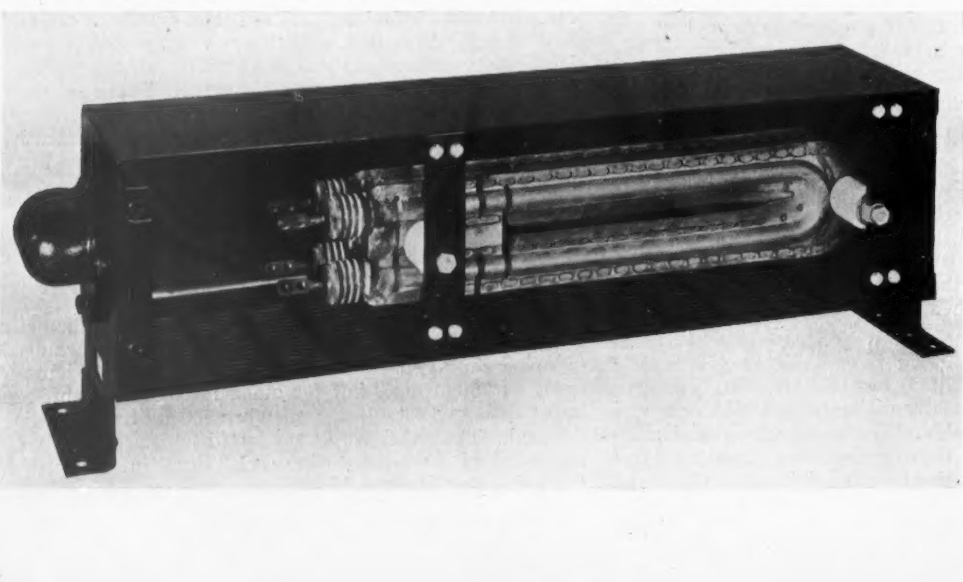


Fig. 13. *General view, with perforated front casing removed, of one of the* 3,000-*volt d.c. electric coach heaters as fitted to the electric stock operating on the Reef*

NEW GOTTHARD LOCOMOTIVE

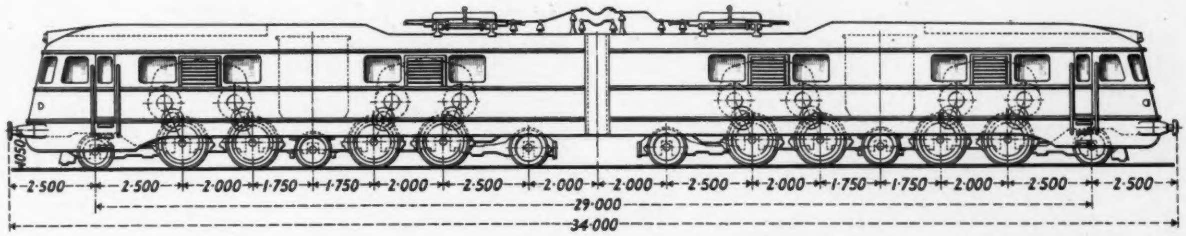


Diagram of the 12,000-h.p. single-phase locomotive now being built for the Swiss Federal Railways

About a year ago the Swiss Federal Railways placed an order for another high-power electric locomotive for the Gotthard line (see issue of this Supplement for February 4, 1938), and it is hoped to show this locomotive at the Swiss National Exhibition in Zurich during the course of the year. It is being built by Oerlikon in conjunction with the Swiss Locomotive & Machine Works, the former being responsible for the electrical equipment, and the Winterthur firm for the mechanical portion.

This locomotive is similar in many respects to the 8,800 h.p. locomotive No. 11851 put into service in 1932, but is designed for a considerably higher rating and can develop a one-hour output of about 12,000 h.p. The same arrangement of axles has been adopted for the new locomotive, and the type is designated Ae 8/14, that is, eight out of 14 axles are driven. The locomotive consists of two halves which are always coupled together in service. It is controlled from one of the two driver's cabs located at each end of the locomotive. The single phase current of 15,000 volts, $16\frac{2}{3}$ cycles is collected from the overhead wire by two pantographs and is led to the two transformers through a circuit breaker.

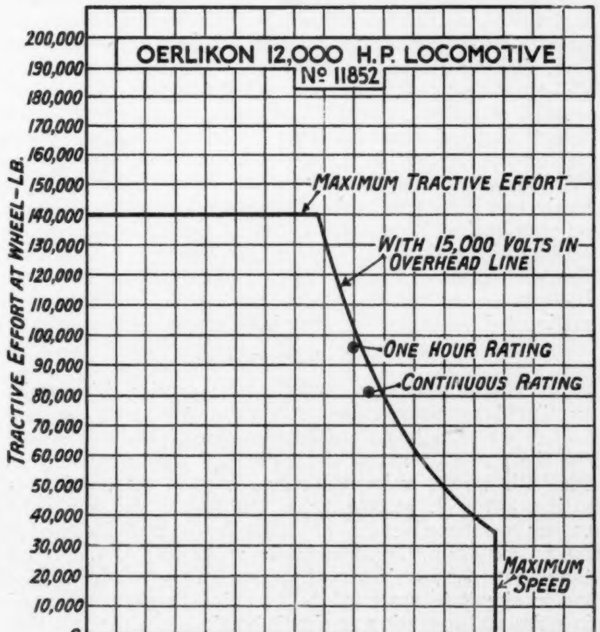
For the speed control of the double locomotive, a newly evolved h.t. control is used, in which the secondary pressure is regulated on the primary side of the locomotive transformers. In view of this, only relatively small currents have to be dealt with, whereas pressure regulation on the low-tension side of the transformers entailed the use of cumbrous control gear for several thousand amperes. Such gear would necessarily have been very heavy and required much more space than the h.t. gear. In the case of the new locomotive, all current leading parts are accommodated inside the transformer tank.

Main Characteristics

The weight of the complete locomotive in working order is about 244 tons and the total adhesive weight about 160 tons. The locomotive can haul express trains with a weight of 600 tons, exclusive of the weight of locomotive, on the gradients of 1 in 38-40 of the Gotthard line at a speed of about 40 m.p.h. Freight trains of about 750 tons trailing can be hauled on the same gradients at about 31 m.p.h. The one-hour rating of the locomotive corresponds to a tractive effort of about 88,000 lb. at a speed of 47 m.p.h.; the maximum tractive effort normally is about 110,000 lb. In order to make it possible to use this high tractive effort effectively at starting, it is necessary that the adhesive weight should be raised from 160 tons to about 172 tons. This is done in a very simple way, by transferring weight from the middle carrying axles, by means of a compressed air weight-reducer. The maximum starting tractive effort permitted by the electrical equipment is 140,000 lb., which can be maintained up to a speed of 39 m.p.h. But related to the maximum adhesion weight of 172 tons, this tractive effort gives a factor of adhesion of only 2·75.

In the case of the previous 8,800 h.p. locomotive of similar design, which was built by the same firms, use was made of the Universal individual axle drive of the Swiss Locomotive and Machine Works. Both the electrical equipment and the mechanical part of this locomotive have proved very satisfactory in service. With this drive, the motors are arranged transversally in the locomotive and work in pairs; each pair of motors drives on to an axle through double reduction gear. The torque is transmitted from gears to driving axle through the intermediary of a movable coupling enclosed on all sides and immersed in oil. This Universal individual axle drive is also used on the new 12,000 h.p. locomotive, and eight motor equipments are required for developing this output.

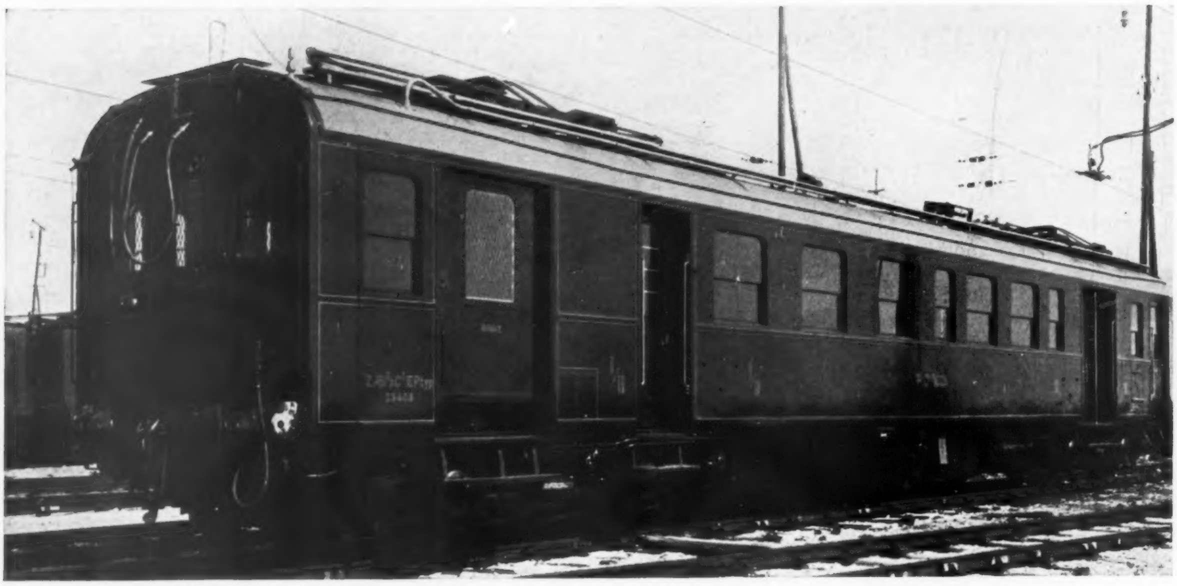
Incidentally, the Oerlikon Company has informed us that the weight of 1,500 tons given on page 1027 of our December 9 issue as the weight of freight trains which could be hauled by the original 8,800 h.p. locomotive, refers only to the loading for level lines. In operation over the Gotthard route the freight train load is limited to 750 tons.



Speed-tractive effort curve of the express 15-kV. single-phase electric locomotive now under construction in Switzerland

A FRENCH STANDARD MOTOR-COACH

Automatic acceleration is incorporated in these powerful units operating suburban and trailer-hauling line services at speeds up to 56 m.p.h.



1,200-h.p. all-steel motor-coach for 1,500-volt d.c. lines

THE present standard electric motor-coach of the Region du Sud-Ouest of the French National Railways (ex-P.O.-Midi system) is a four-motor all-steel vehicle weighing 73 metric tons empty, and having first, second, and third class accommodation and a certain amount of baggage and parcels room. The units to this design, Nos. Z23.401-15, are designed for multiple-unit operation either together or in conjunction with the preceding motor-coaches of series Z23.101-180, which have a somewhat different type of control. Two air-operated pantographs collect the 1,500-volt d.c. from the overhead contact line. Westinghouse automatic air brakes are incorporated and apply two blocks on each wheel through a single cylinder on each bogie. Pneumatic sanding is applied to the outside of the end wheels only. Most of the equipment, including the resistances, contactors, relays, line breakers, reverser, battery, motor-compressor set, and air brake reservoirs, are located below the car floor between the bogies.

Electrical Equipment

Each axle is driven through spur gearing by a self-ventilated nose-suspended traction motor, and the two motors on each bogie are coupled permanently in series. On the one-hour rating the individual motor capacity is 225 kW. at 750 volts 300 amp., and on the continuous rating 173 kW. at 750 volts 230 amp., giving a total output per motor-coach of 1,200 h.p. on the one-hour rating and 925 h.p. on the continuous basis. At 1,200 h.p. the output per metric ton of tare weight is 16·4 h.p. The motor circuit is protected by two line breakers arranged in series and operating as circuit breakers under the action of the overload relays. Starting contactors between the line breakers and the traction motors control the resistances, limit the current at starting, and cut out the resistances in progressive steps. The capacities of the various relays in the 1,500-volt circuits are: overload relays 1,100 amp., acceleration relays 210 amp., shunt relays 180 amp., voltage relays 900 volts (connecting) and 450 volts (disconnecting).

By the provision of special " by-pass " arrangements, five main grouping positions have been obtained, *viz.*, switching (for low speed work only), series, by-pass series by-pass parallel, and parallel. The driving controller itself has 12 notches, Nos. 1 to 6 being for starting in series with the resistances progressively cut out, 7 being the series connection with no resistances in circuit, 8 to 11 parallel connection with decreasing resistances, and 12 the parallel connection with all resistances eliminated. Ten contactors are used to effect the different motor connections as well as to cut out the resistances. After the last full parallel notch a shunted field position is obtained automatically through the action of a commutator group.

Auxiliary circuits fed direct from the 1,500-volt supply are those for the motor-compressor set (through a 20 amp. fuse), for the motor of the motor-generator set (through a 10 amp. fuse), for the car heaters (through a 175 amp. fuse), and for the voltage relays and instruments (through a 2 amp. fuse). A low-tension auxiliary supply at 72 volts is furnished by the 5 kW. motor-generator set, or by a 48-cell 72-volt nickel-cadmium battery, and is used for the electro-pneumatic control system, lighting, Klaxon horn, and pantograph-operating circuits. The low-tension supply voltage is kept constant by means of a special regulator located in the casing below the underframe which houses the smaller auxiliary apparatus.

GLASGOW SUBWAY EQUIPMENT.—During 1938 the General Electric Co. Ltd. supplied seven traction equipments to the Glasgow Subway. Each set included four 65-h.p. traction motors, and a simplified form of electro-pneumatic contactor control gear mounted on a platform.

SOUTHERN RAILWAY ELECTRIFICATION

*By S. W. SMART, Assistant for Train Services, Southern Railway**

WHEN grouping of the railways took place in 1923, the L.B.S.C.R. had electrified 24 route miles, and 17 more miles were in course of conversion; the L.S.W.R. had electrified 49 route miles. Therefore, the Southern Railway, as such, started off with a total of 73 route miles electrified, apart from the Waterloo and City Railway; but whereas the a.c. overhead system had been adopted on the Brighton Section, the d.c. third rail system was in force on the South Western Section. Standardisation was obviously necessary for efficiency and economy, and, after very careful examination, the third rail system was standardised for all extensions, and the overhead system was replaced by the conductor rail system, this conversion being completed in September, 1929. Since the grouping, electrification has been steadily extended with the result that 653 route miles and 1,561 track miles are now electrified, forming the largest electrified suburban system in the world.

The two principal operating advantages that an electric train has over a steam are a quicker rate of acceleration, and the elimination of shunting movements at terminals. As an index of this greater mobility of the electric trains it is to be noted that while the passenger train miles per steam engine hour amount to 11·39, the train miles per electric motor-vehicle hour are 20·09, an improvement of 76·3 per cent.

Suburban Services and Operation

The suburban service to and from London in the rush hours has been increased by 70 per cent., and this increase is attributable to electrification, as the rush hour services had reached the maximum frequency obtainable under steam conditions. The improvement is even more pronounced during the non-rush periods, when the frequency has increased by 149 per cent., thus making ample provision for shopping and amusement purposes. Combining both business and non-business periods, the increase in train frequency is 126 per cent. A further facility has been the opening of a number of additional stations—25 altogether—in the suburban area, bringing the total to 234. The provision of these stations is directly due to electrification as they are situated on congested lines and could not have been served by slower moving steam trains without reducing track capacity.

It may be noted that although throughout the railway only 37·7 per cent. of the Southern Railway's track mileage is electrified, the electric train mileage exceeds the steam passenger train mileage, the figures for 1937 being 32,765,757 electric train miles and 27,554,796 steam train miles. Empty electric mileage is 1·05 per cent. of the total electric mileage. Taking the electrified area as a whole, the average daily number of electric trains per electrified track mile is 71·2.

As steam freight services are too numerous to be restricted to night running only, a number have had to be dovetailed in on tracks carrying as many as eight electric trains an hour. These goods trains have to run strictly to time to avoid delaying the passenger services, the timekeeping of which may be judged from the fact that during last November the average late arrival of 133,938 electric trains on weekdays was 0·59 min. During the same month the average of 63,393 steam trains was 0·76 min. On Sundays, the average for electric trains was 0·24 and for steam trains 0·85 min. late.

The delays due to electrical defects, either in the trains themselves or in the supply of current, are negligible, the figures for November, 1938, when the electric trains ran 3,183,513 miles, being:—

Train defects, 596 min. = 0·72 per cent. of total delay.
Failures of current supply, 10 min. = 0·01 per cent.

Rush-hour Services

The morning and evening business traffic is a great problem. During the 24 hours on weekdays, the S.R. London terminal stations receive 2,545 trains containing about 371,000 passengers. During the three business-period hours from 7.0 a.m. to 10.0 a.m., 540 trains arrive with 243,083 passengers, and if the traffic were evenly spread over the day these trains would have nearly 150 spare seats. But the traffic is so concentrated that about one-third of the day's total passengers, namely, 123,000, arrive during one hour of the morning rush period.

Concentration within the peak period is much more acute now than it was in pre-war days, owing to the standardised hours of labour under which the lower grades start work later and the higher grades earlier, and, in addition, there has been in the last 13 years an increase of 75,823 passengers in these three hours.

The question as to whether any given train should run to Cannon Street or to Charing Cross is a delicate one. In 1925, 11,000 passengers alighted at Cannon Street during the busiest hour; 13 years later the number had increased to 18,000, an increase of 63·6 per cent., but in the same time the number of passengers alighting at Charing Cross during the busiest hour rose from 5,000 to 17,000, an increase of 240 per cent. In the 1925 business period there were 101 trains to these two terminals—36 to Charing Cross and 65 to Cannon Street; 13 years later, in 1938, the number had increased to 126—61 to Charing Cross and 65 to Cannon Street. In the busiest hour 48 up trains pass through London Bridge, 28 going to Cannon Street and 20 to Charing Cross. During the same hour, 44 trains terminate at London Bridge, a total of 92 up trains in one hour. There is a corresponding number of down trains, as for every up train there must be a down train, otherwise the London terminals would become blocked with trains. All these trains are controlled by one signal box at London Bridge. At Borough Market junction the path of the 28 up trains to Cannon Street is crossed by 19 down trains from Charing Cross which have also to fit in with 20 down trains from Cannon Street. The question of overcrowding is given constant attention, and some wider stock is under construction which will give 260 extra seats per train, bringing the seating of a standard suburban train to 912.

In the non-business periods of the day, there has been a still higher percentage increase in the number of passengers. The improved train service between 10.0 a.m. and 4.0 p.m. and again after 7.0 p.m. has produced an excellent traffic, the receipts from which assist in meeting the high cost of the rush-hour traffic. The number of passengers travelling to London daily by the Southern in the non-rush hours has grown from 82,344 in 1925 and 97,401 in 1930 to 127,881 in 1938, an increase since 1925 of 45,437 or 55·2 per cent.

Electrification Results

In the year ending June 30, 1938, the total number of passenger journeys on the Southern electrified lines was 290,000,000, an increase of 2,000,000 compared with the previous year, and of 48,000,000 compared with the year

* In a paper read before the Bristol centre of the Institute of Transport, January 3, 1939.

1932. On the electrified portion of the main line 24,000,000 passengers were carried in the year ending June 30, 1938, an increase of 6,500,000 over 1932, which was the last complete steam year.

On the financial side, the results are equally satisfactory; for the same year the receipts from passengers using the electrified services totalled £8,400,000, an increase of £200,000 over the previous year and of £1,500,000 over 1932. Working expenses have increased, but this is due to a variety of causes, many of which would have occurred under steam working, but this increase is on the total expenditure, not on the train-mile figures.

The financial outlay on electrification has been about £19,000,000. Of this amount about £11,000,000 has been charged to capital expenditure, and the remainder to revenue. Of the charge to revenue, approximately £5,000,000 has been provided from the rolling stock renewal fund, the provision of the electric stock having relieved the company of the liability to renew the displaced steam stock.

When the present programme is completed in July next, there will still be 1,457 miles of line wholly steam operated. There must of necessity be a slowing down of the electrification programme, as most of the areas where the expense would be justified under existing conditions have already been electrified. At the moment, one further extension is under consideration, and two electric locomotives for mixed passenger and freight services are being built for experimental purposes, so that future development may lie mainly in this latter direction.

NOTES AND NEWS

Soviet Electrification.—According to recent statistics, 36 route miles of line in the U.S.S.R. were turned over to electric traction in 1938, bringing the total electrified route mileage at the end of that year up to 1,048. Among the newly-electrified lines are the Olenia-Imandra (Murmansk) section, 22 miles long, and the 11-mile Moscow Tsaritsino section of the Dzerjzinsky railway. It has been stated that freight traffic over the electrified lines has increased by 20 per cent. during the last 12 months.

Switchgear Testing.—Detailed arrangements have now been completed for the testing of switchgear at the stations of the Associaton of Short-Circuit Testing Authorities, as outlined in the issue of this Supplement dated November 11, 1938. Tests will normally be carried out to the short-circuit requirements of B.S.S. No. 116, Part 1, 1937, and the arrangements are limited to a maximum voltage of 11,000 and a maximum rating of 250,000 kVA. The arrangements are in the hands of the Director of the N.P.L., at Teddington.

French Electric Locomotives.—In connection with the electrification of the Tours-Bordeaux line, completed towards the end of last year, orders were placed by the P.O.-Midi, and later by the French National Railways, for totals of 24 standard Bo-Bo and 14 express 2-Do-2 electric locomotives. Practically all of the double-bogie locomotives have now been delivered, but only a few of the express units are in service. In December last the electric stock of the Region du Sud-Ouest (ex P.O.-Midi) comprised 659 locomotives and 151 motor-coaches, inclusive of 10 heavy shunting locomotives and 11 express units under construction. Included in the total were 103 locomotives of the 2-Do-2 wheel arrangement, 10 of the 2-Co-2 type, and 13 metadyne shunting locomotives.

Swedish Electrification in 1939.—In the Swedish budget just introduced appears an allowance of kr. 8,000,000 to start electrification of the State Railways' line between Långsele and Boden in Upper Norrland, which has a length of 310 miles. This electrification, at an estimated cost of kr. 31,000,000, is not considered likely to be as profitable as the conversions hitherto carried out or partly carried out. It is expected that the electrification of the Ånge-Långsele, Bräcke-Östersund, and Gothenburg-Uddevalla lines will be completed in the near future, and electric traction on those lines may be in operation by May 1. When these works are finished, half the total length of the government-owned railway system, carrying 84 per cent. of the traffic, measured in axle-miles, will be electrified.

Electric Goods Working on the Rand.—The administration of the South African Railways has decided to improve freight traffic services on the Rand and to Pretoria by working goods trains electrically over the area between Braamfontein, Germiston, and Pretoria (see map on second page of this Supplement). The section from Pretoria, and including Pretoria West yard, to the yards at Germiston, Braamfontein, and Pretoria and the various sidings and interloops along the route have been installed with the necessary equipment. The section of the Rand mineral line between Canada and Village Main is also to be electrified shortly for passenger traffic, consisting exclusively of natives from the locations at Mlamlankunzi, Orlando, Nancefield, and Pimville. On the Germiston-Pretoria section tests are at present being conducted to ascertain the maximum acceleration which can be obtained. It is possible that the result of these tests may have an effect on the schedules at present in force on the Johannesburg-Pretoria journey.

The greater speed and shorter running times already achieved by electric trains on the Rand during the year the service has been in operation are indicated by the fact that there are now 25 and 30 trains each weekday on the Johannesburg-Randfontein and Johannesburg-Springs lines respectively, compared with 18 and 27 steam trains in 1937. On the Johannesburg-Pimville section 27 trains run at present as against 20 steam trains. On Sundays each of these routes carries four trains more than in the years of steam traction. The saving of time ranges from a minimum of 11 min. on the Johannesburg-Springs fast service, to a maximum of 20 min. on the all-stations Pimville-Jeppe line. The trains stopping at all stations between Johannesburg and Springs now complete the journey in 70 min. compared with 85 min. by steam; the fast trains occupy an hour, or 11 min. less than by steam. All-station trains from Johannesburg to Randfontein now take 63 min., 19 min. less than formerly, and the fast train covers the journey in 55 min.

Publications Received

Electrical Year Book, 1939. London: Emmott & Co. Ltd., 28, Bedford Street, Strand, W.C.2. 6¼ in. × 4 in. 313 pp. and diary. Illustrated. Price 1s. 6d. net.—The thirty-second annual edition of this pocket book has been brought right up to date as regards alternating current systems, single-phase induction motors, and electric measuring instruments. No modifications or additions appear to have been made in the 20-page section on electric traction, and although the general material on this subject is fairly representative of the latest practice, the tables of electrified mileage in various countries give figures which seem to be eighteen months or two years old, and thus take no account of the recent conversion schemes of some magnitude in Italy, France, Poland, and on the Southern Railway in this country.

Electric Railway Traction

Metadyne for Shunting

ALTHOUGH metadyne control has been applied mainly to multiple-unit trains on the L.P.T.B. lines, its earliest traction application was to a shunting locomotive on the ex-P.O.-Midi Railway, on which there are now 14 double-bogie locomotives of 55 tons weight, and the system as a whole would seem to be just as suitable for yard work as for urban and suburban passenger service. In shunting operations the average distance travelled per single movement may well be less than 100 yd., and when the trains are heavy it is important to make the maximum possible use of the adhesion weight. Actual tests show that owing to the absence of current peaks a metadyne locomotive can pull a greater load than can one with a more normal type of control. For example, as stated in the recent paper on metadyne control by Messrs. Fletcher and Tustin, the 55-ton P.O.-Midi metadyne locomotives can start the same train weight as a 72-ton locomotive having ordinary notch control, and careful measurements showed that the equivalent of an increase of 25 per cent. in adhesion was obtained through the use of the notchless controls. From current consumption tests it was found that on different services there was a reduction in current of 28 to 38 per cent., the saving being due to the absence of rheostatic losses. This is particularly noticeable in yard service, where most of the operating time is spent in running at speeds below 9 or 10 m.p.h. with the starting resistances in circuit, and consequent low efficiency, which the metadyne overcomes by its operation without any resistances. With standard types of control the heavy starting currents are being dealt with continuously by contactors, but in the metadyne the control is effected by regulation of the field system, and there is no interruption of the main current. Moreover, as the current taken from the line at the moment of starting is a minimum, there is less tendency to burn the overhead wire before there is movement between the collector and the wire than with more normal types of equipment in which the current taken at starting is a maximum. An interesting application of the metadyne locomotive is to be found in three of the two-power electric-battery locomotives of the 56-ton L.P.T.B., which can operate either on battery power or on current taken from a conductor rail. The notchless control of the metadyne is particularly suited to the inching-forward and slow, steady movements of these works locomotives.

German Electrification Progress

THE electrified length of the German State Railways had risen to 3,290 route km. at the end of 1938, this figure being made up of 2,287 km. from the old Reichsbahn, 915 km. from the ex-Austrian Federal Railways, 61 km. from the Munich Local Railway, incorporated in the Reichsbahn during 1938, and 23 km. from small Czecho-Slovak lines taken over in the Sudeten annexation. The electrified route mileage now amounts to about 5 per cent. of the present total system. The Munich Local Railway is on the 750-volt d.c. system and the Czecho-Slovak lines on the 1,200-volt d.c. system. Electrification in progress includes the Nuremberg—Halle main line and the Stuttgart—Zuffenhausen—Weil der Stadt section. The Salzburg—Attnang-Pucheim section of the ex-Austrian Federal Railways was due to be turned over to electric traction about the end of the year. Electrification extensions on suburban lines now in progress include the 12 km. Priesterweg—Mahlow line of the Berlin Stadtbahn and the Blankenese—Weber line at Hamburg. The Hamburg-Stadt-und Vorortbahn is being converted from 6,000-volt 25-cycle single-phase to 1,200-volt d.c. On the Berlin Stadtbahn arrangements are being made to raise the d.c. voltage from 800 to 900 and to instal automatic voltage regulation. Work is in progress to tie in the high-tension supplies of the Bavarian and Austrian systems, and the first part of the new power station at Muldenstein will come into operation during 1939, and will feed through a 100-kV line leading to Treuchtlingen.

The Third Rail System in Switzerland

AN announcement in the November issue of the *Swiss Federal Railways Bulletin* that an overhead wire has been installed in lieu of the third rail on a short section used by the Fribourg-Morat-Anet Railway is a reminder that there are only two lines in Switzerland using the third-rail system, and in both cases only in part. The Fribourg-Morat-Anet is a standard-gauge line, 32·3 km. (20 miles) in length; the Fribourg—Morat section was opened in 1898, and electrification coincided with the opening of the remainder of the line in 1903. Current is supplied through a side conductor rail at 840 to 950 volts d.c., but the motor-coaches are also equipped with bows for use at stations where there is an overhead wire, and now also between Morat and the junction at Montilier, which section is also used by the Palézieux—Lyss steam trains of the Federal Railways. The other line is the Martigny-Châtelard Railway, a metre-gauge line which connects the main Simplon route with the same gauge Chamonix branch of the former P.L.M. Railway at Vallorcine. It uses overhead contact on the level roadside section between Martigny and Vernayaz, in the Rhone valley, but on the rest of the line the current is taken from a side rail at 750 volts d.c. There is a 2·5 km. Strub rack section between Vernayaz, where the car sheds are situated, and Salvan, with a maximum gradient of 20 per cent. (1 in 5); on the remainder of the route the maximum is 7 per cent. (1 in 14·3). Motor-coaches are used; some are capable of working over the rack section under their own power and others have to be pushed by electric rack locomotives. This line, 18·4 km. (11·5 miles) in length, was opened in 1906, and was electric from the beginning. Its special working arrangements with the French metre-gauge line were described in the issue of this Supplement for October 18, 1935 (page 660), at the time when the old P.L.M. Railway undertook the winter working of the Vallorcine—Le Planet section.

Centrovisory and Automatic Load Control Equipment

A description of the system in use on the 1,500-volt d.c. lines of the New Zealand Government Railways

TWO separate centralised control schemes are used for the control of the traction substations and the transforming station on the electrified sections of the Wellington—Paekakariki main line and Johnsonville suburban line of the New Zealand Government Railways. The scheme used for the main-line substations is known as the tandem scheme, so called because the six substations are controlled over six pilot wires looping in to each substation in tandem. The second scheme, for the suburban line, controls only one substation and is known as the radial scheme. Both are on the Reyrolle Centrovisory system.

The equipment consists broadly of a control desk at the control station and apparatus racks at the control station and at each remotely-controlled substation. A mimic diagram of the controlled system is reproduced on the control desk, see Fig. 1, on which each circuit breaker is represented by a small panel carrying a red, a green, and a white lamp, a selector key, and a hand-operated indicator. A permanent indication of the state of the circuit breaker is given by the lighting of either the green (open) or the red (closed) lamp. To obtain control of the circuit breaker the selector key is depressed and selection begins. The white lamp lights when selection is complete, and shows that operation of the selected breaker is possible.

Selection on the tandem scheme comprises the following sequence. A pair of rotary selector-switches (one at the control station and one at each remotely-controlled substation) step up to corresponding positions, the position depending on the substation at which the selected breaker is situated, *i.e.*, on the key which has been thrown. A stop impulse is then transmitted which locks out the operating circuits at all but the selected substation, and the check-back selection takes place. This consists of the stepping of two further selectors, one at the control station and one at the selected substation, to corresponding positions, which depend on the position of the first selector

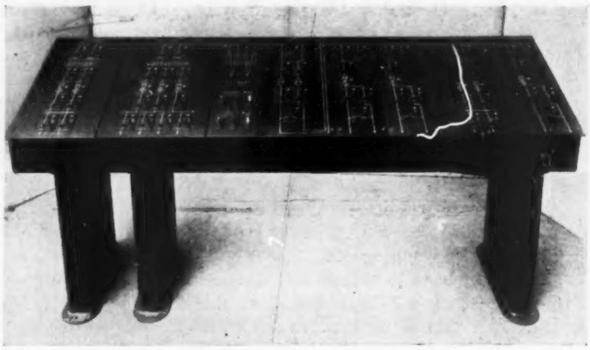


Fig. 1.—Control desk with mimic diagram of the supply and distribution system

at the remote station. If the two sequences have been in perfect synchronism, the two selectors at the control station are in positions similar to the corresponding selectors at the remote station, and station selection has been completed and checked. If for any reason the relative positions of the two control-station selectors are not in the correct checked position, a circuit is not made to the correct check relay, and the equipment automatically clears down at all stations and selection is attempted again. If the two selectors are in the correct relative positions, selection of the required circuit breakers at the selected substation takes place, the sequence being generally similar to that described above, and consisting of the stepping of two selectors (one at the control station and one at the substation) to a position depending on the circuit breaker whose selector key has been operated. This selection is then checked on two further selectors as described above for substation selection and check-back. The four selectors at the control station will now be in

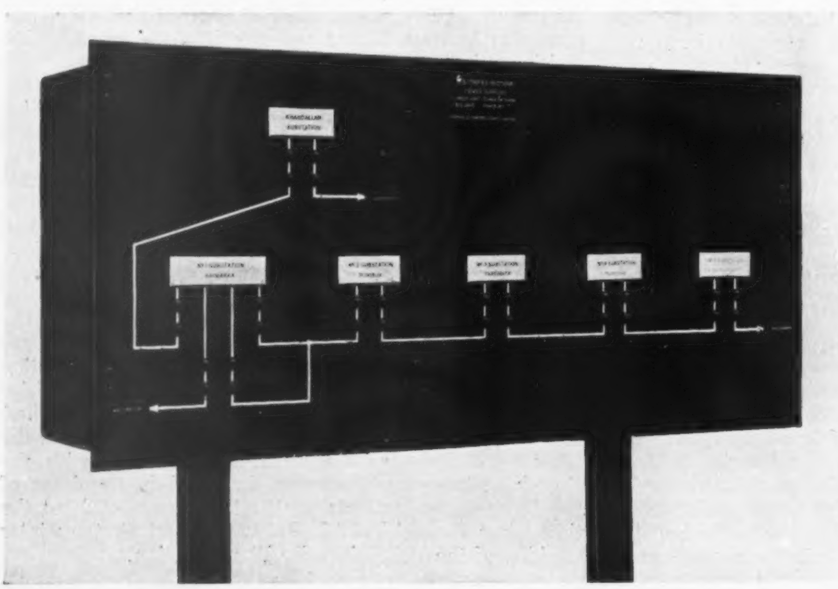


Fig. 2.—Panel provided in the traffic office at Wellington station, giving diagrammatic representation of the electrical conditions on the tracks of the main line and suburban electrified area

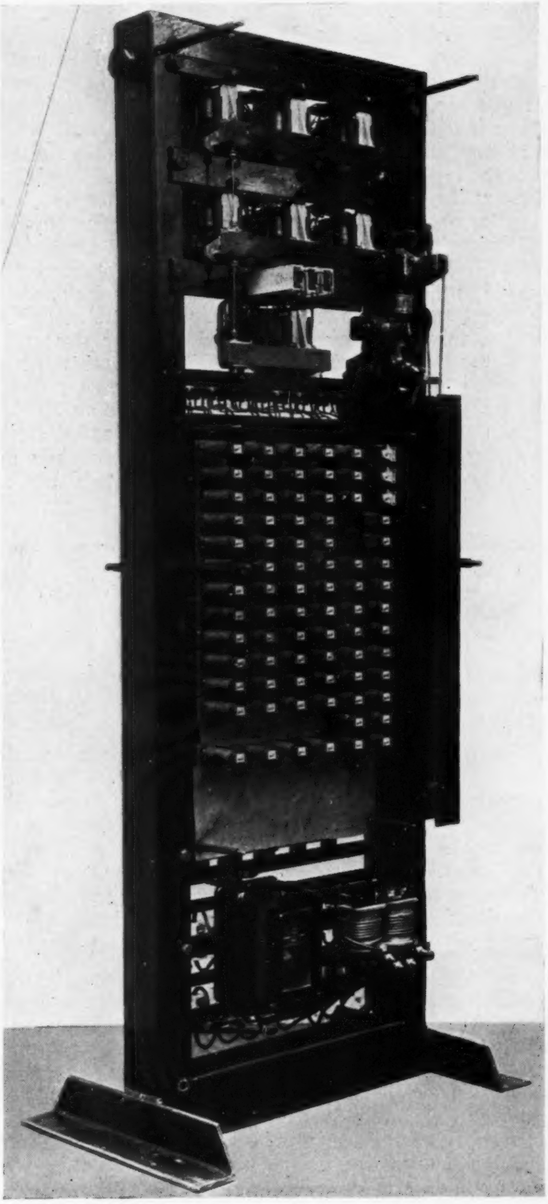


Fig. 3.—Apparatus rack of the Reyrolle selector switches

positions similar to their corresponding selectors at the selected remote station, and this is indicated by the lighting of a white lamp next to the circuit-breaker selector key on the desk. A circuit has now been prepared from the operation-keys on the control desk to the selected breaker close-and-trip relays at the substation and the circuit breaker may be operated as desired.

On the operation of a circuit breaker its condition, *i.e.*, whether closed or open, is automatically indicated by the changing-over of the lighting of the lamps associated with it from green to red, or *vice versa*. When operation is completed, the equipment is cleared down at all stations by restoring the breaker selector-key to normal.

Should any circuit breaker operate by means other than Centrovisory control (*e.g.*, tripping on protection, or manual operation), the equipment automatically selects that circuit breaker position, and signals are transmitted which modify the lamp indication for that breaker, at the same time directing the operator's attention to the change by the sounding of an audible alarm. The circuit breaker affected is distinguishable by the lighting of its white lamp, and after noting the indication the equipment is cleared down and the audible alarm silenced by operating a stop-alarm key. A similar alarm indication is given if a rectifier fault occurs. The operation of the radial Centrovisory control scheme is essentially the same as that of the tandem scheme except that, since only one substation is controlled, no substation selection and check-back is necessary. Hence only two selectors are required at the control station and at the substation, these being for circuit-breaker selection and check-back.

In addition to the indication of the condition of all circuit breakers on the control desk, a traffic-office panel, shown in Fig. 2, is provided in Wellington station, and on it a diagrammatic representation of the electrical conditions of the track is shown. Red and green indicating lamps are associated with each track feed, and these are appropriately lighted to show whether or not the line is being fed by that feeder. The indication is automatically checked (and modified if necessary) after every operation of the Centrovisory control equipment; operation is over eight pilot-cores, and consists of the stepping of a selector switch at the control station. As this switch rotates, a different combination of pilot-relays at the traffic-office is energised at each step, and a different track-indication relay is selected in the panel. These indication relays are then energised or de-energised in accordance with the state of the track, and light green (track live) or red (track dead) lamps.

Unlike automatic telephone-type selector switches, those in the Reyrolle Centrovisory control equipment are not electrically driven, but on each apparatus rack a weight-operated gravity drive is provided to which the selectors are clutched as required, the weights being wound up by small motors controlled by limit-switches. This equipment is clearly shown in Fig. 3, in which the gravity-drive and winding-mechanism are on the right of the rack.

The selectors at the control station rotate steadily, and one ring of contacts connected in the pilots causes the pilot-circuit to be made and broken. The remote-station sensitive pilot relays respond to these impulses, and operate escapements which release the driving mechanisms and cause the selectors to step in conjunction with the control station selectors.

The relays in this scheme are generally similar to those used in telephone practice, except that some of them at the substations are more heavily insulated, and have larger contacts to allow for direct operation of the circuit-breaker trip coils and closing contactor coils. These relays are shown in Fig. 3, on which may also be seen the 230/4-volt transformer for supplying the lamps on the control-desk. For operation of the equipment 50-volt Nife batteries are used at all stations, and at the control station the supply for the desk-lighting can be changed over to the battery in the event of total a.c. failure.

Automatic Load Control Equipment

At substations where more than one rectifier bank is installed, a reserve rectifier can be started when the load exceeds the capacity of the running plant; on the falling-off of the load the reserve rectifier is shut down. The Centrovisory control equipment indicates these operations at the control station by showing the change of state of the a.c. and d.c. rectifier circuit breakers. To discriminate between an automatic shut-down and the tripping of a rectifier on fault, a rectifier-fault alarm as well as the condition of the circuit breakers is signalled in the latter case.

In the two-rectifier substations, either rectifier may be

switched on by Centrovisory or local control, and it remains on load as the base-load rectifier, the second rectifier being controlled by the automatic equipment switching in and out of commission as the load demands. Should the base-load rectifier trip on fault while both are on load, the reserve rectifier automatically becomes the base-load equipment.

At the three-rectifier substation at Kaiwarra, any of the rectifiers may be switched on as the base-load rectifier, and the remaining two will be controlled automatically. The starting of the reserve rectifiers is always in the cycle 1-2-3-1, and the switching-off on the falling-off of load is 1-3-2-1. Thus if No. 2 rectifier is put on base-load, and the loading increased, No. 3 is started, and on a sufficiently high increase No. 1 would start next. On the decrease of load, No. 1 shuts down first, and on a further decrease No. 3 trips out. If any rectifier is shut down for maintenance, a change-over switch is thrown which transfers its control circuits to the next equipment in the cycle, and the station operates as a two-rectifier substation.

Full advantage of the rectifier overload characteristics is taken by the use of thermal relays for load control, these having curves slightly in advance of the specified time-overload curves of the rectifier-transformer units; in addition, an electro-magnetic relay is paralleled with the thermal relay to give instantaneous starting under heavy load increase. These relays are operated by a current transformer in the circuit of the rectifier on load, which means that the current transformer of the rectifier on load works the load control relays of the next unit in cycle.

On starting up, a master timing-device is energised, and drives for about 30 sec., maintaining the closing supplies to the circuit breakers; if at the end of this time either circuit breaker has failed to close, an alarm indication is signalled to the control station, and it is left to the operator to attempt to start up by Centrovisory control. Failing this, the substation must be visited. If the starting is correct the timing relay remains stationary until the load falls sufficiently for the reserve rectifier to be shut down. The timing device is then energised and after an interval of approximately 4 min. (to ensure that the load decrease is not merely temporary) the rectifier circuit breakers are opened and the equipment resets to a position ready for starting up on a further load increase.

Notes and News

Southern Railway Trials.—Trial trips with multiple-unit trains began at the end of January over the Swanley—Gillingham section, which is included in the next electrification extension of the Southern Railway, due to be opened at the beginning of July next.

Electric Locomotive Fire.—One of the 12 single-phase electric locomotives of the Norwegian State Railways used on the Oslo–Lillestrøm suburban trains caught fire during the rush hour on February 1, and the line was blocked for about an hour. The cause was a short circuit in a transformer used for the train heating supply.

Warsaw Black-Out.—Polish urchins recently caused a black-out, and the partial stoppage of the electric train service, near Warsaw, by connecting one end of a wire to a farm fence and throwing the other end, weighted with a stone, over an h.t. overhead cable. Reason being that they had a grievance against the farmer.

Roller Bearing Tests.—Comparative tests with 2-Co-Co-2 electric locomotives of the Japanese Government Railways showed that under winter conditions a locomotive fitted with roller bearings had a starting resistance only 43 per cent. that of a plain-bearing locomotive, and that at normal operating speeds the running resistance was 74 per cent. of the plain-bearing figure.

Irish Electrification Desires.—At the recent annual meeting of the Federation of Irish Industries the statement was made that if the whole railway system was electrified the current consumption would be of the order of 40,000,000 kWh yearly, and that for the £400,000 a year which was now paid for British coal for locomotives a total of 70,000,000 kWh of energy could be generated.

Italian Motor-Coaches.—A total of 45 lightweight motor-coaches, arranged for multiple-unit operation but not for trailer haulage, has been built by Fiat for the 3,000-volt d.c. lines of the Italian State Railways. The motor output is 400 h.p. Baggage room and seating accommodation for 88 passengers in two classes is provided on a tare weight of 32 tons and within a body length of 85 ft. The wheels are 36 in. in diameter, the bogie wheelbase is 9 ft. 10 in., and the bogie centre pitch is 65 ft. 6 in. Two pantographs are fitted. The maximum permissible speed is 110 km.p.h. (68 m.p.h.) and the welded construction of the framing follows the lines of the Fiat Littorina diesel cars.

Danish Electrification Notes.—One of the two pantographs on each motor coach of the Danish State Railways has been provided with carbon contact strips. The remaining pantograph is to retain the original copper strips for the present. In connection with the extension of the Copenhagen electrified suburban system from Valby to Ballerup, conversion work on which is now proceeding, the section from Valby to Vanløse is being doubled.

Japanese Electrification Figures.—According to the report of the Japanese Government Railways for 1936–37, electric locomotives ran 9,594,109 km. in that fiscal year and consumed 97,684,863 kWh. The motor-coach mileage was 131,462,469 km. and the current consumption 240,640,653 kWh. The total current cost for both forms was 6,396,400 yen (17 yen to the £ at the present rate of exchange). At the end of the fiscal year 1936–37 the h.t. electrified route mileage was 388, and the length of the transmission lines was 546 miles, of which 195 miles were at a tension of 60 kV.

Electric Power in New Zealand.—As a result of the extension of the electric power supply from Lake Coleridge to the west coast, which made the power of the Public Works Department available to the railways at Otira, a change is to be made in the source of the supply required for working the Otira tunnel. The current now used is generated from the railway's own steam plant at Otira, but as the new source of supply is more economical, the railway generating station is to be closed and electric power obtained from the national service at Lake Coleridge. The advantages claimed from the change-over are: a guarantee of unlimited power supply at a more economic rate; possibility of extending electrification east and west of the tunnel without new generating plant; and improved efficiency and greater working economy. The scheme will require about 18 months to complete, and when connected, locomotives operating through the tunnel will be able to take heavier loads and longer trains with improved schedules.

A Graphical Device for the Construction of Railway Speed-Time Curves

By D. W. EVANS, A.M.I.E E.

THE choice of electric motors and control apparatus for railway rolling stock to deal most effectively with known conditions of train weight and resistance, track profile and curvature, and time schedule is a process which is generally divided into two distinct stages.

The first comprises the preliminary selection of suitable operating characteristics for motors and control gear. This choice is concerned mainly with the relation between current, speed and torque in the motor, and the number of resistance and field control steps to be provided by the control apparatus. Previous experience and practice are of the greatest importance in arriving rapidly and accurately at such decisions, but it has been shown by Mr. E. T. Hippisley* that the major problem presented in this stage can be stated exactly and solved from primary considerations.

The second stage involves the checking of the decisions made in the first, by applying them in detail to the known service conditions. It is necessary to obtain information, which will be borne out under service conditions, on the following main points.

(1) Heat dissipating, current-carrying and rupturing properties required for all electrical components.
(2) Energy consumption under normal service conditions.
(3) Time schedule to which (1) and (2) apply.

* Journal of I.E.E., Vol. 77, No. 467—November, 1935.

The designer of electrical apparatus is thus furnished with the electrical and physical characteristics required and the prospective operator is provided with means of estimating that part of the operating cost occasioned by the consumption of electrical energy, and also with the means of advance preparation of time-tables. This article deals with the second stage only. To arrive at this information it is necessary to prepare a series of graphs, one for each station to station section, connecting time with train speed, distance travelled, and motor current.

The acceleration of a train varies continually throughout any journey, its variation depending upon the characteristics of the electric motors and control apparatus, and the resistance to motion at various speeds, which is usually variable at irregular intervals due to gradient changes. For this reason, the construction of such a series of graphs becomes a long and tedious process; but there is a graphical method which reduces the number of steps involved without impairing the generally accepted standard of accuracy. As compared with methods in general use, it is claimed that greater speed of working is secured, while the enhanced simplicity militates against those errors which are almost inevitable in a protracted series of calculations, however elementary the calculation itself may be. The method is based upon a principle similar to that used in an article published in the General Electric Review of July, 1936, by Mr. T. F. Perkinson, to whom due acknowledgment is made.

Reference Diagram

The foundation of the method is the preparation of a permanent reference diagram, based upon first principles, and applicable to any proposition within reasonable limits. By plotting on this diagram a curve representative of the service characteristics of the train under consideration, the required increments of time and distance

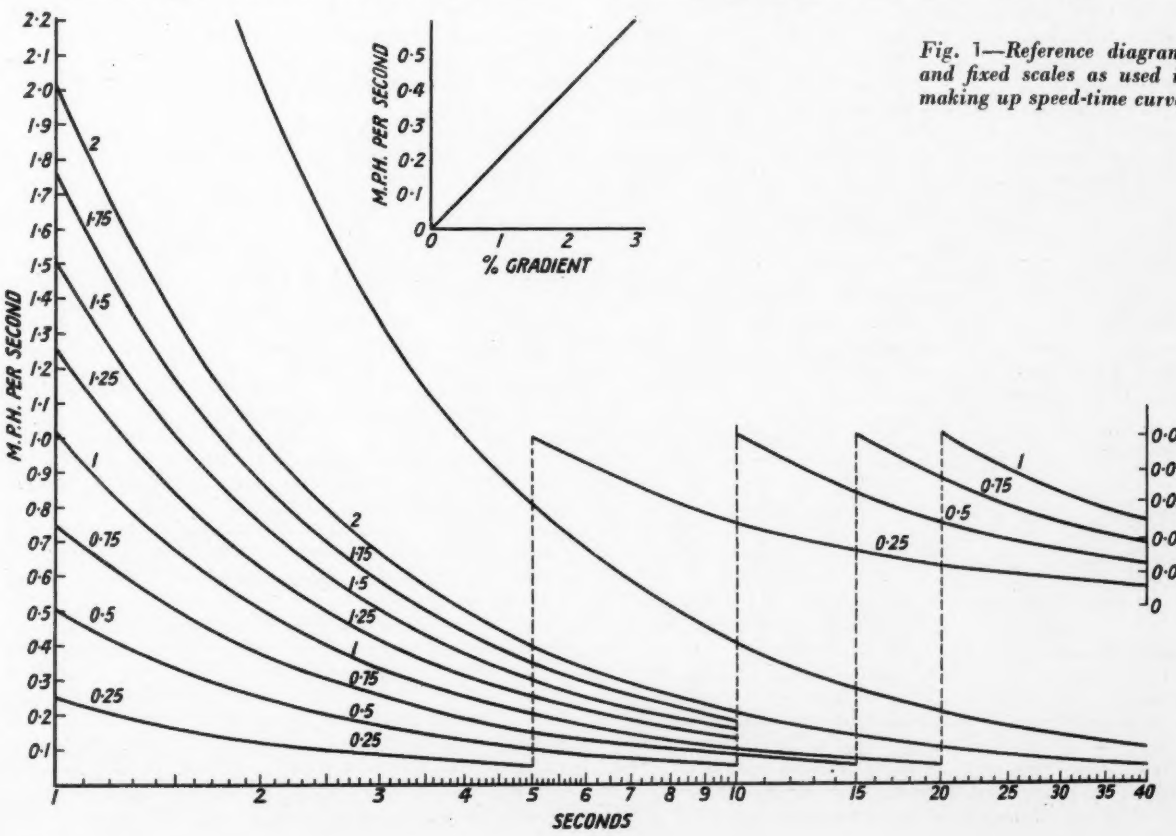


Fig. 1—Reference diagram, and fixed scales as used in making up speed-time curves

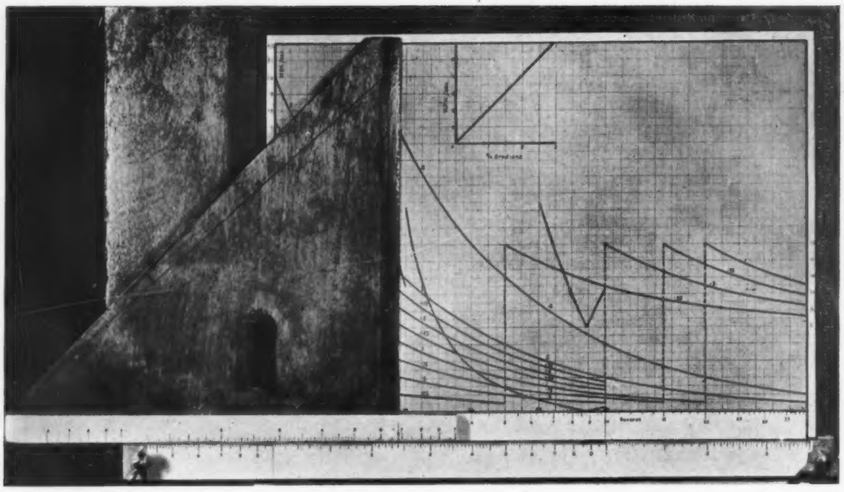


Fig. 2—Calculating board and set square, showing reference diagram, with train-characteristic plotted, clamped in position

for successive intervals of speed are read from the scales of the diagram, and speed-time-distance curves plotted directly from these readings.

Construction of Diagram (Fig. 1).—Although in fact acceleration is varying continually except when a balancing speed is attained, it is sufficiently accurate to assume that during short intervals of not more than about 4 m.p.h., acceleration remains constant. Thus for any short speed interval:—

$$f = \frac{(v - u)}{t}$$

where f = acceleration in m.p.h. per sec.
u = initial speed, m.p.h.
v = final speed, m.p.h.
t = time in seconds.

From this expression, a series of curves can be plotted connecting acceleration and time for various values of the speed interval $(v-u)$. These curves are rectangular in form, and accurate reading at the extremities is impossible; this is overcome by plotting on ordinary squared paper acceleration against $\log_{10}$ time, a logarithmic scale being then plotted along the time axis so that time can be read directly from it. In Fig. 1 the scale for acceleration below 0·05 m.p.h.p.s. has been magnified, and the extremities of the curves plotted to this scale.

Since acceleration during the interval $(v-u)$ is taken to be constant, the distance travelled in feet will be the product of time and the average speed during the interval,

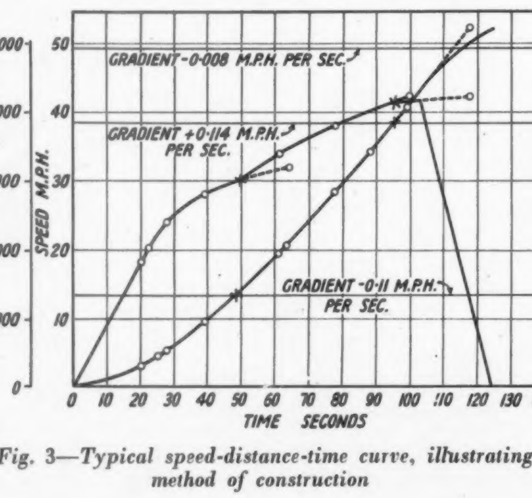


Fig. 3—Typical speed-distance-time curve, illustrating method of construction

multiplied by a constant depending upon the units employed, which for British units is 1·467.

A second logarithmic scale is constructed to dimensions identical with the time scale, but inverted; this scale is arranged to move parallel with the time scale in the manner of a slide rule. A vertical arm extending across the chart is attached to this scale and is offset by an amount representing the constant, in this case $\frac{1}{1.467}$. A prominent mark is made on the scale itself in line with this vertical arm. For any position on the chart of the vertical arm, time can be read from the fixed scale opposite the mark on the moving scale, and distance in feet is read from the fixed scale opposite a number representing the average speed during the interval. The decimal point must be placed as in ordinary slide rule practice.

A useful addition to the diagram is a small separate graph connecting percentage gradient and ± acceleration resulting therefrom. Fig. 2 illustrates a convenient arrangement, in which the fixed scale is mounted on a wooden strip which also serves as a clamp for the chart; the latter is provided with vertical and horizontal lines to ensure accurate location in relation to the scale.

Train Characteristics

In applying the diagram to a concrete case, the first step is to calculate by the familiar step-by-step method a curve connecting train speed and acceleration on level track. For this purpose the train weight and tractive resistance at all speeds must be known; further, a preliminary choice must have been made of motor speed-torque characteristics and rates of acceleration and braking to meet the desired schedule. From these data, the net available tractive effort, and therefore the acceleration, at any speed is known. A curve relating these two quantities is plotted on the chart, using the existing scale for acceleration, and any convenient scale for speed. In tabulating the figures for this curve, it is convenient to read from the motor characteristic the motor amperes, and for each speed point to record the square of the current in one motor, and also the total current taken by the train; these figures are required for subsequent computation of energy consumption and motor R.M.S. current.

Construction of Speed-Time Curves

In Fig. 3 vertical scales are set upon ordinary squared paper for speed (m.p.h.), distance (ft.), train current, and motor current², and a horizontal scale for time (sec.). A series of horizontal lines is drawn through points on the

distance scale corresponding with the distance from the start to each change of gradient on the section of line under consideration; in the space below each line, the value of the gradient is written, expressed as $\pm$ acceleration read from the small graph on the reference diagram.

For the first point, it is required to find the time taken to reach the speed at which artificially maintained constant acceleration ends. This speed and level acceleration are read from the first point on the train characteristic; the acceleration is corrected for the $\pm$ gradient acceleration already recorded, and the time taken is calculated by dividing the speed (m.p.h.) by the net acceleration. The corresponding distance is obtained by multiplying time by average speed (in ft. per sec.) during the interval.

For subsequent points regular speed intervals are taken, and at the mid-point of each interval the ordinate of the train characteristic, corrected as before for $\pm$ gradient acceleration, is marked with the point of a pencil; the point is then transposed horizontally till it lies upon the reference curve corresponding with the chosen speed interval. The square is now moved along until the vertical arm touches the pencil point. Time is read from the fixed scale opposite the index mark on the moving scale in line with the vertical arm of the square. Distance is read from the fixed scale opposite a number corresponding with the speed (m.p.h.) at the mid-point interval, the decimal point being placed as in slide rule practice. The values obtained are plotted as increments to the previous points on the speed and distance curves respectively.

Changes of gradient will be made evident by the fact that the distance curve cuts out one of the horizontal gradient lines. The speed and distance curves are sketched in, and from the point of intersection of the latter with the gradient line, a vertical to the speed curve gives the speed at which the change occurs. For the new gradient, speed intervals are continued from this point, using the new $\pm$ gradient acceleration as already recorded.

When the distance curve reaches the last of the gradient lines, the cut-off point for brake application must be determined. A trial point is chosen on the speed curve, the corresponding distance and time being noted. The braking time (sec.) is obtained by dividing cut-off speed (m.p.h.) by the chosen rate of braking (m.p.h.p.s.). The braking distance (feet) is obtained by multiplying time by the average speed during braking (feet per sec.). Adding this to the distance at the cut-off point, the total should equal the length of the section under consideration; if the error is considerable, other trials must be made.

This completes the speed and distance curves for the fastest possible schedule; a second braking line is drawn through a point on the time axis representing the maximum time permitted by the stipulated schedule. Choosing a cut-off point on the speed curve, a line is drawn, the slope of which represents the coasting deceleration derived from the known resistance to motion at the average coasting speed, as augmented or decreased by the average value of gradient during the coasting period. The distance travelled is calculated as for braking, and other trials are made until this coincides with the length of the run.

From the tabulation made for the train characteristic, values of train amp. and motor amp.^{2} are read for various speeds, and are plotted at times corresponding to these speeds on the speed-time curve. The areas of these curves give train amp.-sec. and motor amp.^{2}-sec. from which energy consumption and motor r.m.s. amp. are calculated.

Metadyne Control for Urban Trains

According to the paper on the metadyne and its application to electric traction read before the Institution of Electrical Engineers on February 23 by Messrs. G. H. Fletcher and A. Tustin, of the Metropolitan-Vickers Electrical Co. Ltd., the L.P.T.B. first tried in experimental service a two-car underground train with metadyne control, but to gain further experience, particularly in multiple-unit operation, a six-car train comprised of three two-coach units was ordered subsequently. The results were sufficiently encouraging for the L.P.T.B. to place an order for 58 equipments—all for the District line type of train, and most of these are now in traffic. Compared with the trial equipments, the mechanical arrangement has been modified in that the exciter and regulator dynamo, instead of being overhung at the end of the main machine, are made as a separate two-bearing set, coupled to the armature of the metadyne through a flexible coupling. Certain modifications have also been made in the connections, the chief being that to improve the method of producing the back e.m.f. in the metadyne before connecting to the line, the part of the winding used for entry in regeneration has been shunted to reduce the rate of rise of flux, and so avoid excessive "transformer" voltage in the commutating coils.

The 3 m.p.h.p.s. service rate of braking is too high to permit of 100 per cent. braking being obtained on the motor axles without exceeding adhesion limits, and air brakes are therefore applied to the carrying axles at the same time as regeneration is applied to the driving axles. When the regenerated current falls to a predetermined low value during normal braking, air brakes are automatically applied also to the motored axles. During normal braking about two-thirds of the total braking effort is applied through regeneration, and one-third by the air brake. This reduces the total regenerated energy, and the energy returned to the line is approximately 15 per cent. of the amount taken when motoring.

Regenerative Braking

The regenerative braking notches are combined with the Westinghouse electro-pneumatic brake and are operated by the same handle. There are two regenerative braking notches, the first giving a low rate of deceleration suitable for checking when approaching signals, and the second giving maximum possible regeneration with simultaneous application of the air brakes to the carrying axles. Further notches give electro-pneumatic braking on all axles and Westinghouse emergency braking without regeneration, so that air braking is always available by a further movement of the controller. All these brakes are operated from the brake controller, but the application of the brakes in a normal stop, although initiated through the controller, is actually controlled by two mercury retarders which operate, when the braking rate is too high, first to stop the application, and, if the rate is still too high, to reduce the application by blowing off air.

The master controller has three motoring notches, giving (1) low initial acceleration and low balancing speed, (2) high initial acceleration and low balancing speed, (3) high initial acceleration and high balancing speed. Notch (1) is suitable for shunting and for sections where the maximum demand on the line must be limited, notch (2) for normal running up to a top speed of 35 m.p.h., and notch (3) for high acceleration without speed restrictions.

Some Technical Aspects of Railway Electrification

*By J. E. CALVERLEY, M.I.E.E., Chief Engineer, English Electric Co. Ltd.**

MUCH of the investment in electrification is largely independent of the amount of traffic. For example, the current-collection system must be installed irrespective of the number of trains operating. Substation equipment will to a certain extent depend upon traffic, but locomotives and rolling stock are wholly dependent. If the capital is considered to include the substations but not the e.h.t. supply, the following percentages may be taken as representative of the distribution of capital outlay on a typical electrification scheme :—

	Per cent.
Substations	15
Track equipment	25
Rolling stock	48
Alterations, interest and sundries	12
	100

Against the gross capital expenditure a credit is due for steam locomotives, rolling stock and plant which will no longer be required. The value of this credit is difficult to estimate, and at best it would reduce the new capital required to about 80 per cent. About half the investment is proportional to the traffic, from which it follows that there is a minimum traffic figure at which it is economical to electrify. The Weir Report (1931) found this to be—in the case of Great Britain—rather over 2,000,000 trailing-ton-miles per mile of running track per annum, while the actual average density was estimated to be 3,000,000.

Motor Characteristics

The principal characteristics of an electric motor are torque, speed and efficiency, and for traction purposes torque and speed are expressed as tractive efforts in pounds at the wheel tread and m.p.h., plotted against motor current. The variation of the field strength of a motor has an important bearing on the speed, for the stronger the field the lower will be the speed. If the field is maintained sensibly constant, such as in shunt-connected motors, the speed will also remain fairly constant, dropping off only at the higher loads, due to armature reaction and resistance losses. If the field is connected in series with the armature and so carries the local current, the speed characteristic is very different and falls rapidly with increasing load. Output being proportional to the product of torque and speed, it will be realised that under starting conditions the series-wound motor is ideal for traction work, in that it gives a high tractive effort at a comparatively low speed.

Speed being dependent on field strength and applied voltage, so far as d.c. machines are concerned, the only economical method of speed control is by varying the field or by series-parallel connection if more than one motor is used. The line voltage being constant, to vary the terminal voltage entails the insertion of resistance and the consequent loss of energy. The series motor is quite unstable as a generator, but a shunt machine is stable either when motoring or generating. Intermediate characteristics are obtainable by the use of both shunt and series fields, a combination known as compound winding. Compound motors can be designed for a large range of field control and yet retain much of the series characteristic, which is desirable in traction work. They offer a degree of electrical stability which is desirable under all conditions, and particularly when it is required to change over from motoring to generating, as in regenerative braking.

To calculate the performance of a locomotive or motor-coach train is a straightforward though tedious business. It is most convenient to ascertain the load per motor, and treat the resistances to motion at so much per ton of load. These latter are made up of acceleration, grade, and track resistances. The first two are quite definite quantities, but the third is subject to considerable variation. In suburban operation by far the greater part of energy expenditure is incurred during acceleration, when the motor must exert at the wheel tread 112 lb./ton/m.p.h.p.s., as against, say, 10 lb./ton for track resistance. As a result, on typical runs a 50 per cent. error in the track resistance will not affect the energy consumption calculation by more than 5 per cent. In main-line operation an accurate knowledge of track resistance is of greater importance, but there are ample data available from long experience. The series motor has a characteristic at its higher speeds which gives a large variation of speed for a comparatively little change in current, and energy consumption calculations are usually within 2·5 per cent. of actual results.

Since each speed is associated with a definite current, a current curve over a period can be plotted, the area of which enables the mean value to be obtained. This, multiplied by the voltage, gives the energy consumption and forms the basis for the loading of the substation and power supply system. The curve of current squared is also important, for this enables the root mean square current to be obtained, and the r.m.s. current is a measure of the heating in the motor.

Full line voltage cannot be applied to a stationary motor, the resistance of which is so low that the resulting current would operate the protective breakers even if it did not do serious damage to the motor and the control gear. The current must be limited to the value required for accelerating the train. As the motor speed rises, the back e.m.f. builds up, and the difference between this and the line voltage progressively declines. In practice, the vast majority of control systems, whether a.c. or d.c., effect this operation by a number of steps, so that the accelerating current varies between limits. The torque associated with the mean current must give the required acceleration, but the maximum torque must not exceed the slipping value of the wheels on the rail.

Control and Adhesion

One point regarding adhesion arises particularly in suburban services, where the tendency is to call for increasing schedules which entail still higher rates of acceleration. The variation of tractive effort shown in the notching curve of a control system may be of the order of ±20 per cent., but if means were available for maintaining the current at a constant value during acceleration, the acceleration would correspond with the maximum and not the mean current. Accordingly, attention is being focussed on control schemes designed to this end, such as the metadyne which is in operation on the L.P.T.B., and of the Rheomutor, which is in course of development.

[Mr. Calverley concluded his paper with an interesting study of conductivity and substation spacing which it would be unwise to abstract ; that section of the paper should be read *in extenso*.—ED.]

* In a paper read before the Manchester Association of Engineers, January 27

Electric Railway Traction

Southern Electrification Figures

SPEAKING at the annual general meeting of the Southern Railway on February 23, Mr. R. Holland-Martin, the Chairman, said that during the year 1938 there had been an increase of £180,000 in the revenue from the electrified area, which result would give an indication of how much the Southern owed to its electric services. In every case conversion had brought a net income largely in excess of the interest required for the capital expenditure. The Portsmouth No. 2 electrification—that is, the Mid-Sussex route—opened to electric traction in July last, had experienced an increase of over 13 per cent. in gross receipts during the first six months; the Sevenoaks line, over which electric trains began to run early in 1935, had shown a further increase of 5½ per cent. in revenue during the year just passed; the Alton, Staines, and Guildford *via* Woking routes had shown an increase of 9 per cent., and the Guildford—Portsmouth route an increase of 9½ per cent. Against these increases in the electrified areas the company suffered a decrease of £60,000 in the revenue from its other passenger traffic. The company was devoting much attention to the rush-hour problem, for in the three hours between 7.0 a.m. and 10.0 a.m. the London terminals of the Southern received a total of 540 trains carrying 243,000 passengers, out of a total of 2,545 trains and 371,000 passengers during a 24-hr. period. Multiple-unit electric traction alone had made possible such figures, but in the last ten years the general length of the platforms had increased from 600 ft. to 700-800 ft. As a result of the greater use of steel and of welded construction, it had been found possible to gain a few inches in the coach width; this, combined with a further small gain through a different contour for the body, had enabled six-a-side coaches to be built, and thus to increase considerably the carrying capacity.

The Metadyne in Service

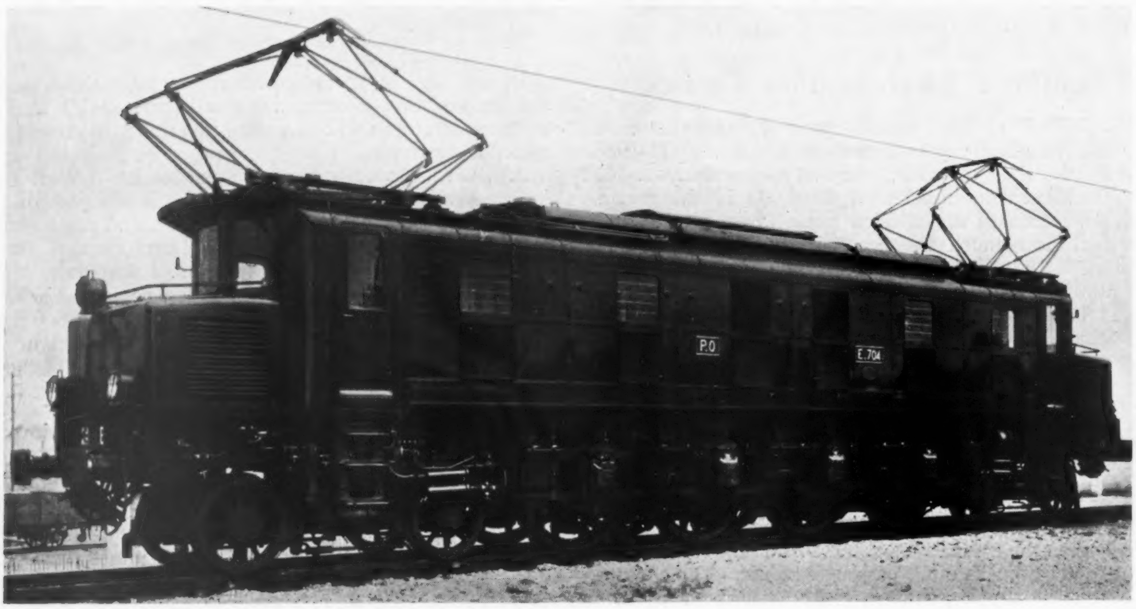
DURING the discussion on Messrs. Fletcher and Tustin's paper on the metadyne system of control before the Institution of Electrical Engineers on February 23, Mr. W. S. Graff-Baker, Chief Mechanical Engineer to the London Passenger Transport Board, said that on the results given by the apparatus fitted to the L.P.T.B. trains he was by no means dissatisfied with metadyne equipment. Although the motor had to be switched on twice between start and stop, he did not think the maintenance would be higher, and the motor would be less likely to experience the temperature changes of an ordinary traction motor. Although there appeared to be a good deal of electrical equipment attached to the metadyne system, the contactors were small and were not specially troublesome. In the calculations previous to adopting the metadyne, no allowance had been made for regenerated current being absorbed into the supply system through the substations; the economy calculated was based on the regeneration absorbed into the track and taken up by any train working in that section. With 40, or even 20, trains an hour it was not difficult. Current saving could not be measured at the train, but had to be measured at the substations, and it was the intention to carry out shortly one week's working with regeneration and one week without, so that the saving could be measured. One of the principal problems of the L.P.T.B. train operations was brake blocks. With 3,000 cars in service, something approaching 4,000 tons of cast iron brake block dust was lost each year, and much of that metal found its way into the electrical equipment. On the Hammersmith and City line the life of the brake blocks on the metadyne trains was 800 miles, compared with an average of 540 miles on the other trains on the remainder of the system, despite the slightly heavier weight and greater speed at the point of braking of the metadyne trains. The saving was not in the brake shoe cost alone, but also in the labour involved in renewing the shoes.

A Notable Motor-Coach Design

OVER the Paris—Le Mans main line of the French National Railways the old slow steam trains operating the stopping services between Chartres, Nogent-le-Rotrou and Le Mans have been replaced by single-unit electric motor-coaches having several remarkable characteristics. These vehicles do not haul trailers, but can be operated two or more in multiple-unit if traffic necessitates. Although designed specially for these stopping services, the maximum designed speed is no less than 140 km.p.h. (87 m.p.h.) and the acceleration of the order of 1 metre (3·28 ft.) per sec. per sec. Greatly accelerated schedules have thus been made practicable, and with a top speed at the moment of 120 km.p.h. (75 m.p.h.) the schedule from Chartres to Le Mans, 124 km. (77 miles) is 100 min., equivalent to 74·4 km.p.h. (46·2 m.p.h.) inclusive of 16 intermediate stops, and these cars have shown themselves quite capable of maintaining end-to-end speeds of 90 km.p.h. (56 m.p.h.) with stops on the average every 7 km. (4·35 miles) and with a maximum speed of 140 km.p.h. (87 m.p.h.). A seating capacity of 78, together with a small amount of luggage space, is provided on a tare weight of 38½ metric tons, of which the electrical equipment accounts for 12 metric tons. According to French computations, there is nominal standing room for 55 passengers and for 118 as a maximum. The four traction motors have an aggregate one-hour rating of 825 h.p., giving 21½ h.p. per *tonne* of tare, and 16 h.p. per *tonne* of gross weight under the maximum loading conditions. The motors drive the 35½-in. wheels through resilient gears, and the two motors on each bogie are connected permanently in series. A new form of Alsthom control, without starting resistances, has been embodied, and includes eleven notches for series working and ten notches for series-parallel connection. Braking is effected by automatic air and rheostatic systems, and normal stops are made by these two working in conjunction, and controlled by a single driver's handle. With both systems in operation the motor-coach can be brought to rest from 140 km.p.h. (87 m.p.h.) in 850 m. (930 yd.), but during special tests a stop from 156 km.p.h. (97 m.p.h.) was made in 950 m. (1,040 yd.) in 33 sec. with only the air brake in operation. The maximum speed attained during tests has been 166 km.p.h. (103 m.p.h.).

HIGH-SPEED TEST RUNS IN FRANCE

Some notes on the track performance and the proportions of the electrical equipment of one of the locomotives used



4,950-*h.p. locomotive which has attained* 115 *m.p.h.*

SEVERAL high-speed test runs with 2-Do-2 electric locomotives have been made on the French National Railways during the past twelve months, and in the course of one of them the ex-P.O. Schneider-Westinghouse 136½-*tonne* locomotive No. E.704 hauled a trailing load of 176 metric tons, composed of four carriages, at a speed of 180 km.p.h. (112 m.p.h.) for 2 km. (1·25 miles) and at 185 km.p.h. (115 m.p.h.) for 1 km. (0·62 miles). Over a 20-km. (12½-mile) section between Blois and St. Pierre-des-Corps the locomotive maintained a flying average of 170 km.p.h. (105½ m.p.h.) in each direction. Neither the locomotive nor the carriages of the train were streamlined. At a speed of 168 km.p.h. (104¼ m.p.h.) the resistance of the train including the locomotive was equivalent to 11·2 kg. per *tonne* (25 lb. per ton).

Locomotive No. E.704 is one of four different trial locomotives set to work in 1934, at a time when it was desired to obtain an increase in output compared with the then standard 2-Do-2 locomotives of the P.O. Railway. Actually, the one-hour output of the trial machines represented an increase of 20 to 25 per cent. over the older E.500 series, and later locomotives for the P.O.-Midi and Etat systems were based on the design of the trial units of 1934.

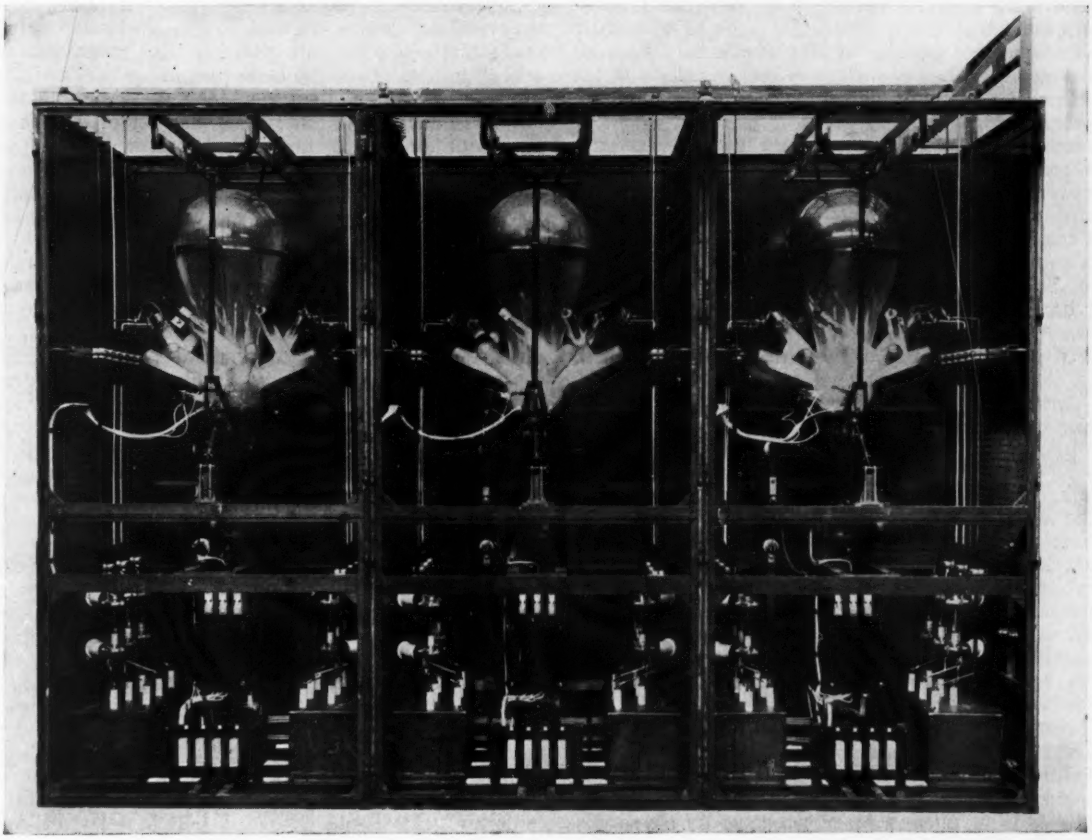
The mechanical portion of No. E.704 was built at the Creusot works of Schneider, and the electrical equipment was constructed by the Soc. Schneider-Westinghouse, with the collaboration of the Westinghouse Electrical & Manufacturing Company. The mechanical portion weighs 86·3 *tonnes* and the electrical equipment 49·3 *tonnes*. Each pair of 69-in. wheels is driven by a twin-armature four-pole motor through the medium of the Westinghouse form of cup drive. The two armatures of a motor are connected permanently in series, and with a line voltage of 1,350 (the nominal figure is 1,500 volts) the output per motor on the continuous rating is 1,075 h.p. at 635 amp. 1,140 r.p.m with shunted field. On the one-hour rating the individual motor output is 1,240 h.p. at 722 amp. and 1,040 r.p.m. with shunted field. The corresponding locomotive outputs at the wheel rims are 4,300 h.p. at 106 km.p.h. (65·8 m.p.h.) and 4,950 h.p. at 96·5 km.p.h. (60 m.p.h.) with a line tension of 1,350 volts. The maximum measured power at the pantographs has been 6,000 h.p. at a speed of 90 km.p.h. (56 m.p.h.). The weight of a motor without gears or quill is 6·1 *tonnes*, equivalent to 10·8 lb. per h.p. on the one-hour rating. The armatures are supported on roller bearings and normally these run 240,000 km. (150,000 miles) without renewal of the lubricant, as do the various lubricated parts of the individual axle drive. The motors are force-ventilated by two 675-volt motor-blower sets each with a capacity of 6,600 cu. ft. per min.

The electro-pneumatic control system provides 15 economical speed notches with four motors in operation, and with series, series-parallel, and parallel connections, and also five notches with only two motors in operation. Field reduction up to a maximum of 50 per cent. is obtained by tappings and shunts. Regenerative braking is incorporated and the excitation current is obtained from two 1,350/45-volt 22-kW motor-generator sets.

A maximum tractive effort of 53,000 lb. can be exerted at the wheel treads, and against the adhesion weight of 80 *tonnes* gives a factor of adhesion of 3·33. The rigid wheelbase is 6·06 m. (19 ft. 10 in.), the total wheelbase 14·4 m. (47 ft. 3 in.), the overall length 17·78 m. (58 ft. 4 in.), and the height of the centre of gravity about 1·57 m. (62 in.). The bogie wheelbase is 2·4 m. (7 ft. 10½ in.) and the bogie wheel diameter 965 mm. (38 in.). The maximum braking force from the air brake system is equivalent to 96 per cent. of the weight on the driving wheels.

The Evolution of Electric Traction Substations

By C. E. FAIRBURN, M.A.,
*Deputy Chief Mechanical Engineer and Electrical Engineer, L.M.S.R.**



Half of a 1,200 kW Hewittic six-bulb rectifier set, Lancashire electrified lines, L.M.S.R.

EARLY d.c. substations on 600/800-volt systems relied almost entirely on the rotary converter which, at that time, could not operate satisfactorily with a supply frequency as high as 50 cycles, and this led to the use of 25 cycles or 33⅓ cycles for many important power stations, such as Lots Road, Greenwich, Stonebridge Park, and Formby.

As design information increased, it was found possible to build rotary converters for a 50-cycle supply. In France a number of such machines were installed on 1,500-volt lines and they were quite satisfactory under normal conditions, but they were unable to withstand disturbances on either the a.c. or d.c. systems, and flashovers and other troubles were experienced to a greater extent than with the low-frequency machines. These early 50-cycle rotaries were designed for output voltages not exceeding about 750 volts, and two were used in series on 1,500-volt d.c. systems. After the problem had been made easier by the development of high-speed circuit breakers, single machines for 1,500 volts were built. For 3,000-volt systems, it was necessary to use motor-generator sets, which although easier to design and more reliable in operation on any supply frequency, are less efficient than rotary converters. Satisfactory 50-cycle 3,000-volt rotary converter plant has not been evolved.

The first mercury-arc converters were of the glass bulb type, such as the Cooper-Hewitt, and were made only in small units of little use in traction work, but eventually the water-cooled steel tank type was developed, and in time units able to deal with the power and voltages needed for d.c. traction became available.

Between 1910 and 1929, some 620 steel tank rectifier plants, comprising 1,300 units of an average rating of 730 kW., were installed on railways and tramways throughout the world; of these, 41 per cent. operated at voltages up to 750, 54 per cent. from that voltage up to 1,650, and the remainder up to 3,000 volts. In 1910, it required an 18-anode unit to rectify 150 amp.; by 1924 a dozen-anode unit could carry 1,500 amp. ; and by 1927 such units could carry 6,000 amp., and currents as large as 16,000 amp. have been rectified by single cylinders. In this country, the first steel tank rectifier to be installed by a main line company was put into commission in 1931, on the Manchester—Altrincham line, and in 1932 the first glass bulb rectifier to be used for railway traction in the world was put into service on the Liverpool—Southport line.

The attempts at simplification have been in two direc-

* In a paper before the Liverpool Engineering Society, February 15, 1939

tions: to eliminate the vacuum pumping system, or at all events to avoid the need for keeping it in operation continuously, and to use air-cooling instead of water-cooling. In a type developed by a British manufacturer both these aims have been accomplished. The vessel is made from relatively thin steel plate with welded joints, and is roughly the same shape as a glass bulb unit. The seals are formed from vitreous enamelled steel cones fused together, the whole being welded in place so that there are no demountable joints. Cooling is effected by an air stream directed on to the surface of the cylinder and the anode arms by deflectors. Single units carrying **750** amp. are in service.

The characteristics of any mercury vapour converter can be greatly modified by fitting "grid control"; this term covers the actual grids in the rectifier and the associated auxiliary equipment. On d.c. systems, grid control makes it possible to regulate the d.c. output voltage, to suppress the arc completely for protection under fault conditions, either in the rectifier equipment or on the a.c. or d.c. networks and to operate the converter as an inverter. The extent to which grid control has been utilised in practice for any of these purposes is restricted, and the only case where it is in extensive use is on the South African Railways, where it is used for voltage regulation and inverted operation of a **3,000**-volt system.

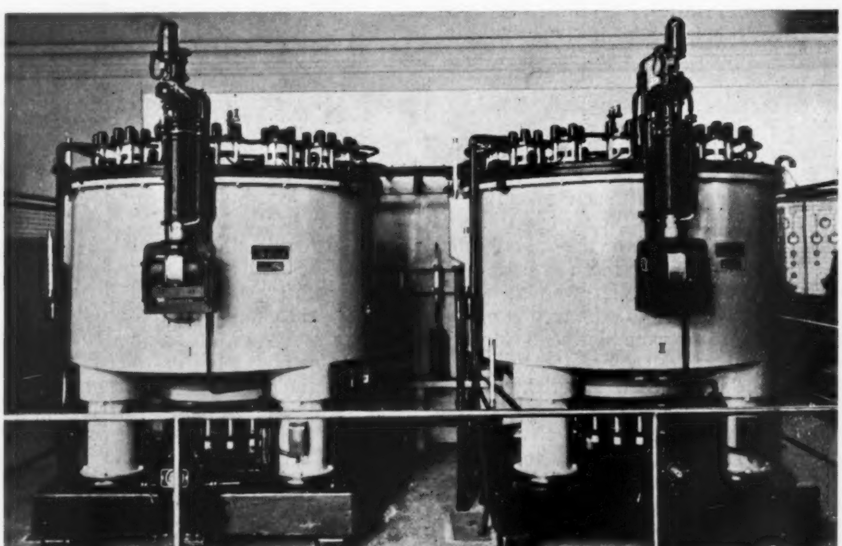
Frequency Converters

On a.c. systems, the grid-controlled converter can replace the motor-alternator three-phase to single-phase converter sets which are expensive and have a low efficiency. The first large-scale trial installation has been put into service in Germany, near Basle; the results obtained are apparently successful, and further improvements may be expected with longer experience. The advantages gained are illustrated by the increase in the average service efficiency from **66** to **81** per cent. and the floor area required is reduced by one-half. The control equipment is complicated and requires a large number of thermionic valves of limited life; but if this part of the equipment can be simplified the operation of the plant will probably become simpler than that of rotating machines, as it will be less liable to be affected by disturbances on the supply system. In this installation, the three-phase and the single-phase systems are coupled rigidly together, but other equipments in experimental use permit independent frequency changes in the two systems, and this may be an important advantage in some instances as it would enable a single-phase system to be fed from two or more independent three-phase systems.

Most of the improvements in a.c. switchgear have been obtained by fitting arc-extinguishing devices to the contacts of switches of otherwise standard construction. When switches so fitted are opened under load, part of the resulting arc is formed in an enclosed space, so generating a gas pressure which is used to drive a jet of cool oil into or across the main part of the arc, extinguishing it more rapidly than would be the case with simple switch contacts. In some cases this jet of oil has been caused or assisted by mechanical means, such as pistons deriving their operating forces from the switch mechanism. As a result of the success of these devices, manufacturers have turned their attention to providing switches in which the quantity of oil is reduced to a minimum, largely with a view to reducing the fire risk, and such types are used fairly extensively on the Continent. Success has also been achieved with circuit breakers without oil. In some of these a blast of air is used to extinguish the arc. The air is stored in pressure cylinders and released immediately the switch contacts open by a valve operated from the switch mechanism. These breakers become inoperative if the air supply should fail and they are noisy in operation. In other types the construction resembles that of the minimum oil-type breaker, but special liquids are used instead of oil.

D.C. Switchgear

The high-speed d.c. circuit breaker, originally developed to simplify the problems associated with rotary converter design, is now universally employed for feeder protection in d.c. substations, and it has proved itself valuable in limiting the disturbance caused by track faults. These breakers take two forms, one a development of the normal speed breaker in which the breaker is held closed by a mechanical catch and provided with a high-speed mechanism, and the other in which the breaker is held in magnetically and released by diverting the holding flux. Both types have magnetic blow-out coils. A fault can generally be cleared in **0·01** to **0·02** sec., and in most designs the breaker setting is influenced by the rate of rise of fault current, so that a heavy fault is cleared before the current has risen to its maximum value. The



3,600 kVA grid-controlled mercury vapour frequency converter as used on the Baden electrified lines of the German State Railway. It is used to convert 45-kV 50-cycle three-phase supply to 15-kV 16·6-cycle single-phase current for the overhead contact line

types with magnetic holding are tripped only by an overload current in one direction; a reverse current cannot trip them, and this feature can be used to give discriminating protection, which is valuable when the contact rails or conductor wires of adjacent tracks are bonded at points between substations to give better voltage regulation on the trains. A recent innovation is the plug-in type high-speed breaker unit. This enables a breaker to be isolated very readily for maintenance work and a defective unit can quickly be replaced.

The lack of flexibility of the automatic substation to meet abnormal operating conditions, such as fog, has greatly restricted its use, but considerable success has been attained when limited to track feeder breakers. There are two methods in use. In one, when a feeder breaker has opened as the result of an overload or fault current, it recloses automatically after a predetermined period. If it fails to remain in, this is repeated several times and the breaker then locks out. In the other arrangement, after a breaker has tripped it recloses with a resistance in series to limit the current which can flow. If the magnitude of the resulting current shows that correct conditions have been established on the system, this resistance is then shorted out; if not, the breaker opens again.

The disadvantages of the automatic substation are overcome by remote control apparatus. The equipment used falls mainly into three classes. The earliest used multicore cables between each substation and the control point, each conductor being used for one function only, either to give an indication of some condition in the substation or to control an item of the equipment, for example, a circuit breaker. The objection to this arrangement lies in the high cost of the multicore cables, and has led to modifications in which the conductors are used for more than one purpose.

The second class uses apparatus which has been specially developed for the purpose to enable a single pair of conductors to control a substation, or sometimes several substations connected to the conductors in tandem. They depend upon the selection of a particular pair of contacts in the substation according to the setting of the apparatus at the control point, or *vice versa* if an indication is to be sent to the control room. The third class also operates over a single pair of conductors and uses apparatus of the type which has been developed for automatic telephone exchanges, the positions of the selector mechanisms in the substations and the control point being determined by the transmission of codes made up from series of impulses.

The following figures relate to an intended reconstruction of the substation system of the Euston—Broad Street—Watford lines of the L.M.S.R. The existing substations were designed just before the war, and their capacity was increased in 1932. The scheme is to include the modernisation of Stonebridge Park power station. The existing distribution voltage of 11,000 will be retained but the frequency will be changed from 25 to 50 cycles. The number of substations, all to be of the single unit type, will be increased and remote control will be employed.

L.M.S.R. North London Electrified Suburban Lines

	Existing	Proposed
Number of substations	10	17
Average distance between substations	3·8 miles	2·2 miles
Direct current demand (half hour)	23,000 kW	22,500 kW
Type of converter unit	Rotary converter	Mercury-arc rectifier
Number of converter units ..	39	17
Total capacity of plant	37,500 kW	34,000 kW
Average rating per unit	960 kW	2,000 kW
Average floor area of substation	4,500 sq. ft.	1,500 sq. ft.
Total floor area of substations ..	45,000 sq. ft.	25,500 sq. ft.
Average cubic capacity of substations	140,000 cu. ft.	24,000 cu. ft.
Total cubic capacity of substations	1,400,000 cu. ft.	408,000 cu. ft

To sum up, the position appears to be that on d.c. railways rotating plant is now obsolete and the types of equipment which are being installed today are firmly established. On single-phase lines, the displacement of rotating plant is only beginning and many features of the mercury-arc converters, which it may be expected will be used, are still undetermined. A.c. switchgear is undergoing rapid changes; the lines of development seem fairly clear as far as the oil circuit breaker is concerned, but it appears probable that the oil-less types will find increasing use especially on high-voltage circuits. The high-speed d.c. breaker does not appear likely to be modified to any great extent, as the performance of existing types may be considered as very satisfactory.

Up-to-date d.c. switchgear on the Wirral electrified lines of the L.M.S.R. These high-speed breakers are rated at 1,200 amp.; the breaker on the left is a reverse-current breaker in the supply from the mercury arc rectifier

Map of the Sydney suburban lines, New South Wales Government Railways, showing lines electrified and to be electrified
(see opposite page)

SYDNEY ELECTRIFICATION EXTENSIONS

FOR over ten years now the greater part of the passenger traffic in the Sydney metropolitan area has been handled by electric trains and trams. For the purpose of railway working the surrounding country lying within 34 miles of Sydney is considered as being within the suburban area, and within this boundary there are 185 route miles of railway, with electric operation to approximately 20 miles from the city and with steam operation for the outer area. The electrified route mileage at the moment is about 94, all on the 1,500-volt d.c. system with overhead current collection.

Within the electrified area there remain small sections of railway still operated by steam trains or by railcars of one form or another. The desirability of converting these sections has long been recognised, and acting on the recommendation of the New South Wales Commissioner for Railways, the State Government has provided funds for the electrification of the Kingsgrove—East Hills and Regent's Park—Bankstown lines. The lines from the city to Regent's Park and to Bankstown are already electrified, and when the 3-mile Bankstown—Regent's Park connecting line is converted, a saving in both journey times and operating costs will be possible. The conversion of the East Hills line will enable passengers from the city to that district to travel without change of train, which now has to be made at Kingsgrove.

A further short conversion for which funds have been provided is that from the line at Sefton Park to Chullora junction and the electric car repair sheds, over which hitherto electric vehicles have had to be hauled dead by a steam locomotive. The electrification of this short line and of the two passenger lines noted above will bring the electrified route mileage of the New South Wales Government Railways up to 107 from the present total of approximately 94, and the electrified track mileage to something over 300.

L.N.E.R. Electrical Equipment Orders

THE L.N.E.R. has placed contracts for the passenger coaches to be used on the lines now being electrified between Liverpool Street and Fenchurch Street and Shenfield, and between Manchester and Glossop. They will be of all-steel construction and of the open saloon type and will be fitted with electro-pneumatic doors which may be opened by the passenger pressing a button or may be controlled by the train staff. Contracts have been placed with the Metropolitan-Cammell Carriage & Wagon Co. Ltd. for 100 60-ft. motor coaches and 100 55-ft. composite trailer coaches, and with the Birmingham Railway Carriage & Wagon Co. Ltd. for 100 55-ft. driving trailer coaches. Orders have also been placed with the English Electric Co. Ltd. for 92 three-coach electric train equipments for the Liverpool Street—Shenfield trains, and with the General Electric Co. Ltd. for eight three-coach electric train equipments for the Manchester—Glossop trains. The total value of these orders is over 1½ million pounds.

The Manchester—Glossop train equipments comprise motors, control gear, auxiliaries, heating, lighting, and automatic door gear wiring. In the design provision has been made for line voltages up to 1,800 on account of the regenerative braking incorporated in the locomotives. The trains are to comprise one motor-coach, one composite trailer, and one driving trailer. Each motor-coach is to have four self-ventilated traction motors with an individual one-hour rating of 220 h.p. The control gear is to be of the electro-pneumatic unit switch type mounted beneath the car underframe.

The English Electric contract for the 92 Shenfield line trains comprises the complete electrical equipment for three-car sets, each made up of one motor-coach, one trailer, and one driving trailer. The four traction motors on each motor-coach are to have an individual one-hour rating of 210 h.p. The heating circuit will be at 1,500 volts, and a motor-generator set in each motor-coach will supply 50-volt current for lighting and control.

Work has been in progress for the last twelve months on both the Manchester—Sheffield scheme (of which the Glossop services form part), and on the Liverpool Street—Shenfield scheme. The Shenfield electrification will cater for an intensive suburban passenger traffic, whilst on the Manchester—Sheffield—Wath lines electric traction will be adopted for all classes of traffic, including a very heavy goods and mineral traffic. The two schemes together will cost more than six million pounds and they are being undertaken by the L.N.E.R. as Government Assistance schemes in accordance with the London Passenger Transport (Agreement) Act of July, 1935, and the Railways (Agreement) Act of December, 1935.

Notes and News

Australian Inquiry.—The State Electricity Commission of Victoria is calling for tenders, by April 18, for the supply of two double-bogie central cab electric locomotives to operate over 990-mm. gauge lines in and around the Yallourn brown coal works.

Electrification Paper.—Mr. W. J. England, Assistant Superintendent of Operation, Southern Railway, is to read a paper on " Some Incidentals of a Railway Electrification Scheme " before the Institute of Transport on April 3. The meeting is due to begin at 5.30 p.m., and will be held at the premises of the Institution of Electrical Engineers.

Soviet Electrification.—A new programme of railway electrification has been drawn up by the Soviet authorities, and apparently seeks to make up the deficiencies of the second Five-Year Plan and subsequent programmes, during which something less than 700 route miles have been converted, compared with 3,000 miles planned. Included in the new proposals are extensions in the Donbass, Caucasus, and Murmansk areas.

Dutch Extension.—The Netherlands Railways have sanctioned the electrification on the standard 1,500-volt d.c. system of the Arnhem-Nijmegen and Breukeln-Harmeln lines, with an aggregate route length of 16 miles. The former is a southern extension of the present Utrecht—Arnhem electric services, and the second route gives a connection between the Amsterdam—Utrecht and Utrecht—Hague lines, avoiding Utrecht, and thus provides a shorter electric route, 78 km., between Amsterdam(Weesperpoort) and Rotterdam(Maas) than the usual 86-km. Amsterdam (Central)—Haarlem—Rotterdam(Delftschepoort) line.

THE MOSCOW METRO

Its present status

AFTER the trial opening of the Moscow Metro in November, 1934, and the official opening of the first section in May, 1935, three years elapsed before any further lines were opened to regular traffic, except for the short extension over the river to the Kiev station, in 1937. The first section comprised the Sokolniki—Gorki Park and Ohotni Riad—Smolenskaia lines, with the subsequent extension to the Kiev station. The second section was the 2½-mile Pokrovski line from near the Lenin Library to the Kursk station, with one intermediate station at Ploschad Revolutsi, opened on March 13, 1938. On September 11 of the same year the much longer Gorki line, from Sverdlovsk Place to Sokol, 6 miles, was opened, bringing the route mileage to a total of 16½.

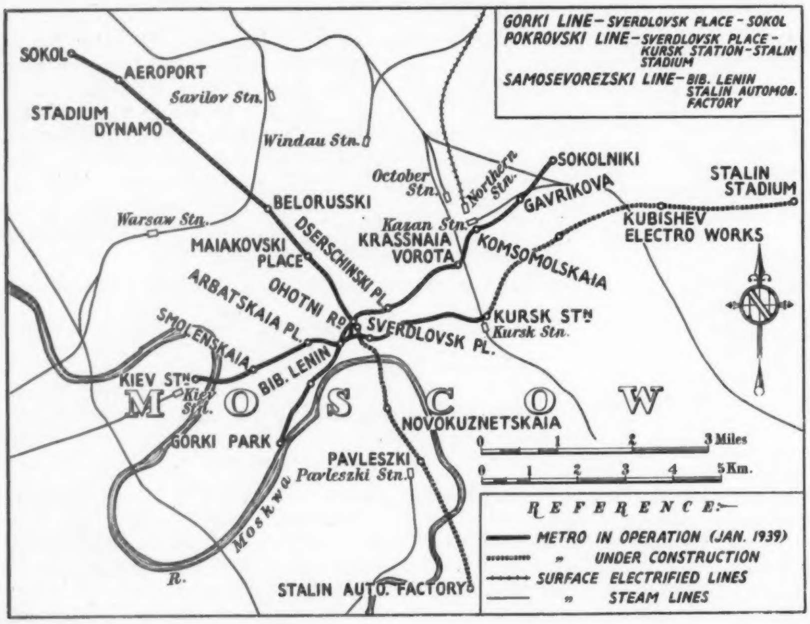
Two further extensions are now under construction, *viz.*, the Samosevorezski line from Sverdlovsk Place to the Stalin automobile factory, and the extension of the Pokrovski radius from the Kursk station to the Stalin stadium. These lines will be 4 and 4½ miles long respectively. Several further routes are planned, and some of these will be circular lines, as contrasted with the existing routes, all of which are radial. One of the main purposes of the non-radial lines, such as the Sadovaia circle, is to reduce the transfer traffic at the city stations in the neighbourhood of Sverdlovsk Place and Ohotni Riad. Taken generally, the radial lines follow reasonably closely the routes proposed some eight or nine years ago before construction of the first Metro section was begun, but the circular routes are new proposals based on traffic experience and the requirements of other districts.

On the Sokolniki—Kiev station and Gorki Park sections of the Metro the average distance between stations is little more than half a mile, but on the new Pokrovski extension still under construction, the distance will be about 1¾ miles. On the Gorki line the stations are not more than 1·4 miles apart, and some of them are a good deal less. Start-to-stop speeds of 25 to 26 m.p.h. are proposed for the Pokrovski and Samosevorezski line services, compared with about 22 m.p.h. on the Gorki line and 19 m.p.h. over the Sokolniki—Kiev station line. When the original sections were opened in 1935 the start-to-stop speeds averaged about 16½ m.p.h. Stations on the two lines opened during 1938, and on the future extensions, take trains of eight 62-ft. cars.

Throughout the day a six-minute service is maintained over the radial and diametral lines, but during the rush hours there is a four-minute headway on the Pokrovski—Arbat diameter, and a 2½-min. headway on the other lines. At the end of 1935 the number of passengers carried a day was about 175,000, but by the beginning of 1938 the number had risen to over 450,000. Since the opening of the Kursk station and Gorki lines the number carried is reported to have reached three-quarters of a million a day, equivalent to about 11 per cent. of the whole of the railway, bus, and tram traffic in Moscow. On May 1 last year, that is, before the Gorki line was in operation, the Metro carried 720,000 passengers.

In accordance with previous practice, the stations on the Gorki line are all to different designs. Sverdlovsk Place has walls and pillars faced with white marble and decorated with porcelain bas-relief representations of the peoples of the U.S.S.R. Maiakovski Place is built entirely of metal with facings of rust-proof steel, and has 36 cupolas decorated with mosaic panels depicting a day in the land of Socialism. Belorusski (or White Russian) station is decorated with rose-coloured marble, Aeroport with light-coloured marble, and Sokol with red and rose marble. Dynamo station has its exits leading direct on to the stadium grounds. Cast iron sectional rings, with sound insulation, are used for the tunnel lining on this section, and the track is supported on concrete without the use of ballast. Long welded rails are used. Nine six-car trains were built for the Gorki line.

Both the Samosevorezski and Pokrovski extensions are being constructed at a general depth of 30 to 35 m. (100 to 115 ft.) below the surface, and where the former passes below the river it is at a depth of about 20 m. (65 ft.) below the bed. At the deep level stations escalators are being installed, and will have a speed of 2¾ to 3 ft. per sec., compared with less than 2½ ft. at present.



Map of the Moscow underground lines showing routes opened and under construction. The trains collect power at 750 volts d.c. from an under-contact third rail. The installed traction substation capacity for the lines now opened is about 70,000 kW., and the substations are automatic in operation. There are 16½ route miles of double-track line with 22 passenger stations. The track mileage is about 50

Electric Railway Traction

Something New in Suburban Trains

A NEW triple-unit articulated train designed for silence and comfort has been introduced experimentally on the Brooklyn-Manhattan Transit lines in New York. There are eight General Electric traction motors with an aggregate output of 720 h.p., and with the 150-notch control are designed to accelerate the set from rest to 20 m.p.h. in only six seconds. The controller can be set to give automatic acceleration at rates averaging 2, 3 or 4 m.p.h.p.s. The braking gives a maximum deceleration rate of 4 m.p.h.p.s. and comprises air and electric brakes. Braking is initiated by the rheostatic equipment, using the motors as generators, and is continued thus down to a speed of 4 or 5 m.p.h., when a transition to the air brake is made automatically. The last notch on the braking side of the controller brings into action an electro-magnetic track brake. The energy from the electric brake is dissipated in resistances, and the heat thus generated is used to heat the three-car train during cold weather; a supplementary effect is obtained by electric heaters taking 600 volts d.c. direct from the conductor rail. Built principally of extruded sections and plates of aluminium alloy by the Clark Equipment Company, the three-car set has a length of 80 ft. 4 in., tares 76,000 lb., seats 84 passengers, and has a large amount of standing room. There are rubber insets in the wheels and a large use is made of rubber springs and cushioning blocks at various points on the bogies. Forced ventilation with filtered air is another feature. The normal top running speed is 40 m.p.h.

Railway Electrification in England

THE fact that in England there are electrified railways aggregating about 990 route miles (equivalent to 2,410 track miles) is largely due to the perspicacity of the Southern Railway and the London Passenger Transport Board and its forerunners, for together these two systems account for no fewer than 800 route (1,960 track) miles. Even though the L.N.E.R. is engaged in converting some 100 route (400 track) miles, the totals of three of the four main-line companies are disappointing, and show that outside London no large-scale effort has ever been made to build up big suburban traffics by providing really up-to-date facilities. As indicated in the first portion of the joint review of electric traction in England as presented by Messrs. Agnew, Thompson, Voelcker, and Cansdale before the Institution of Locomotive Engineers on April 19, the English electrified lines are operated by over 7,400 motor-coaches and trailers and 25 electric locomotives, the great difference in the totals being due to the fact that since the electric traction on the L.N.E.R. Shildon—Newport line ceased, the only electrically-hauled freight service has been over the Newcastle Quayside branch. Actually, the authors do not record this, and the locomotive total should be increased by three to cover the Bo-Bo steeple-cab units built for that line more than 30 years ago. Up to the end of 1938 only 5 per cent. of the total route mileage in England was electrified, but in view of the immense traffic carried by the Southern electrified services and on the L.P.T.B., the traffic dealt with electrically must far exceed 5 per cent. of the total. With the exception of the Manchester—Bury (1,200-volt d.c.), Manchester, South Junction & Altrincham (1,500-volt d.c.), and Lancaster—Heysham (6,600-volt single-phase) lines, aggregating 32 route miles, low-tension (600-660 volts) d.c. is universal, and only the M.S.J.A., Lancaster—Heysham and Newcastle Quayside lines have overhead current collection.

The Berthing of Multiple-Unit Trains

AMONG the details requiring attention when an electrification scheme is under way are the stabling and cleaning of the stock, particularly with multiple-unit operation. The Southern Railway, one of the largest users of multiple-unit electric trains in the world, has evolved standard berthing sheds for electric stock, and cross sectional drawings were reproduced in the issue of this Supplement for June 25, 1937. One of the most important of the Southern's sheds is that at Streatham Hill, as emphasised by Mr. W. J. England, Assistant Superintendent of Operation, in his recent paper to the Institute of Transport, abstracted elsewhere in this issue. It is used for stock coming out of service from London Bridge and Victoria termini, and also is a relief to the big depot at Selhurst. It is located 7¼ miles from London Bridge, 5½ miles from Victoria, 6¼ miles from Blackfriars, and 6¾ miles from Holborn, and its work will be further extended by the opening of the Gillingham electrification extension during the coming summer. At present the depot comprises an eight-road inspection and cleaning shed with four 546-ft. roads to hold eight-car trains and four 820-ft. roads to house 12-car sets. Due to the exigencies of space, the five berthing stages, with accommodation for 89 vehicles and provided with appropriate water and lighting services, are located on the opposite side of the running lines. At the Victoria end of the depot is a carriage-washing machine through which the trains pass immediately on their arrival. Cleaning of the train interiors is facilitated by a central vacuum cleaning plant with leads from overhead pipes to the heads used by the staff, and also by the provision of mobile platforms which can be pushed along the side of the train. No conductor rails are laid in the sheds, for reasons of safety, and movement of the train units is carried out by means of jumper cables permanently attached to an overhead trolley system, and which can be plugged into a motor-coach of the train set. Few other railways provide such ample shed accommodation for their passenger rolling stock as the Southern, and the type of shed evolved as standard is of a highly practical yet economical design. The structure is of steel framing covered with stout corrugated asbestos, and ample lighting is provided both by side windows and roof lights. By night the electric lights are well placed, so that cleaners and those whose duty it is to attend to the maintenance of the equipment are never obstructed by inadequate illumination. Nor is there any lack of water where it is needed, nor of drainage, and not only are the trains kept clean and in good repair, but the sheds themselves are also kept in this condition.

TORQUE AND DRAWBAR REACTION

A study in which the theory and the influence of the various components is dealt with in preference to giving tabulated data of various locomotive classes

By E. H. CROFT, A.M.Inst.C.E., A.M.I.E.E.

AN elementary example for the examination of torque and drawbar reaction is that of a two-axle locomotive operated by one pair of driving wheels, and with the wheels driven by an armature mounted on the axle and a field system mounted on the locomotive frame; in other words, the so-called "gearless" electric locomotive. For the sake of simplicity it may be assumed that the resistance to motion of the locomotive is negligible compared with the drawbar pull.

There are obviously two alternatives to this elementary case, namely, one in which the driving axle is leading

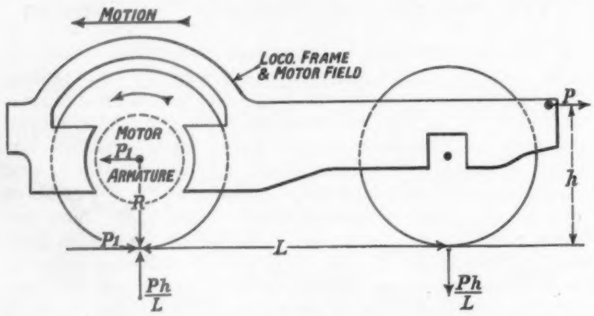


Fig. 1—Conditions with gearless motor and driving axle leading

and one in which the driving axle is at the rear. The former case is indicated in Fig. 1 and will be investigated first. Unless otherwise stated it is assumed that the drawgear is connected at a point above the axle level. Let P be the drawbar drag exerted on the locomotive by the train, h the height of the drawgear above rail level, R the driving wheel radius, and L the wheelbase.

To move forward the pull of the train, P, must be overcome, and the driving wheel can only transmit the force to the frame at the axlebox. Thus the wheels must be rotated counter-clockwise with a torque $P_1 \times R$ where $P_1 = -P$. To turn the wheels in this way the frame will be subjected to a couple $-P_1 \times R$ or $P \times R$. Only the four wheels can create the reaction, and thus the downward force on the back wheels will be $\frac{PR}{L}$ and the upward force on the front wheels $-\frac{PR}{L}$. Thus the weight on the back wheels will increase and on the front wheels will decrease, due to the effect of the torque reaction.

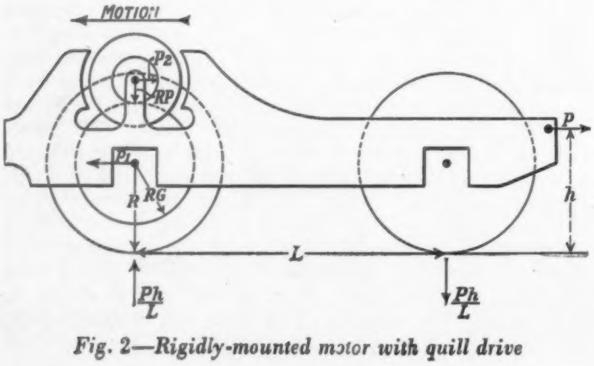


Fig. 2—Rigidly-mounted motor with quill drive

The force P_1 and the drawbar pull of the train also cause a couple to be exerted on the locomotive frame, of the same sign as the torque reaction and equal to $-P(h-R)$. This is conveniently termed the drag reaction. If the torque reaction be added to the drag reaction the total drawgear reaction Ph is obtained. For a two-axle vehicle this latter result is obvious, but the method adopted of dealing with the torque reaction separately is of great advantage in considering more complicated cases and illustrates the difference between the two component reactions. The total increased load on the back wheels thus becomes $\frac{Ph}{L}$ and on the front $-\frac{Ph}{L}$. It follows that if the rear wheels are driven all the forces will be the same relative to the direction of motion, and the importance of a rear wheel drive for a uni-directional vehicle is clearly demonstrated.

Fully to appreciate more complicated cases it is desirable to consider the effect, if any, of the usual methods of mounting the motor. First, consider a motor rigidly mounted in the frame, but driven by some form of gear, *e.g.*, the Westinghouse quill drive. An elementary diagram of such a drive, corresponding in other respects to Fig. 1, is shown in Fig. 2. In this example the gear ratio is

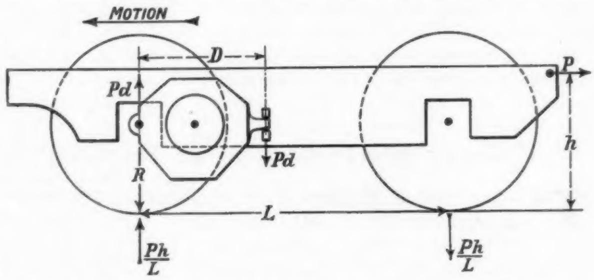


Fig. 3—Two-axle vehicle with one nose-suspended motor

represented by g, the gear wheel radius by R_g, and the pinion radius by R_p, all other symbols remaining as before in Fig. 1.

The wheel torque can only react on the frame through the armature bearings. Thus the value of the force at the gear wheel circumference $P_g = P \times \frac{R}{R_g}$ and the value of the reaction at the armature bearings must also be $P \times \frac{R}{R_g}$. Thus the torque reaction of the frame $P \times \frac{R}{R_g} \times (R_g + R_p) = PR \times (1+g)$. The armature torque reaction is $PR \times g$ in the opposite direction. Thus the total torque reaction on the locomotive is PR and the weight transfer is the same as the previous case. This result is really self-evident on a two-axle bogie, but it is desirable to consider the action of the motor torque reaction. In this case also the weight transfer will be identical if the rear wheels are driven instead of the front.

A further elementary example needs investigation,

namely the case of an axle-hung motor. Although the method of suspension does not affect the question of weight transfer of a two-axle bogie, it does affect the weight transfer of some types of wheel arrangement. Fig. 3 represents a two-axle vehicle driven by one axle-hung motor, but in other respects similar to the cases represented in Figs. 1 and 2.

The distance of the motor nose suspension from the axle is represented by D, and all other symbols are the same as in Figs. 1 and 2. The reaction to the wheel torque is the couple acting on the axle direct and the nose suspension. Thus $P_dD = PR$ and $P_d = \frac{PR}{D}$. The P_d downward force on the nose suspension becomes $P_d \times \frac{L-D}{L}$ on the front axle and $P_d \times \frac{D}{L}$ on the rear axle. Thus the weight transfer to back axle is $\frac{PR}{D} \times \frac{D}{L} = \frac{PR}{L}$ and transfer from front axle is: $P_d - P_d \times \frac{L-D}{L} = \frac{PR}{D} - \frac{PR}{D} \times \frac{L-D}{L}$ $= -\frac{PR}{L}$.

Thus when the drawgear reaction is added the weight transfer remains as in all other cases. Calculation on the same lines will indicate that the effect is not changed by the suspension point being fixed outside the wheelbase, nor by the motor being suspended on the back axle. An investigation of a two-motor two-axle bogie on the same elementary lines, with fully springborne or nose-suspended motors, indicates at once that the method of suspension has no effect on the weight transfer, as would be expected.

The Three-Axle Bogie

In the case of the three-axle locomotive or bogie, the calculation of weight transfer can no longer be based on the elementary calculation of drawbar reaction, but must be calculated by considering the various components, which have been indicated in the previous elementary considerations of the two-axle bogie. In addition, the effect of the axlebox spring grading must also be taken into account. This is a feature omitted by many writers. In the first case (see Fig. 4) the motor will be assumed to turn the wheels by means of some form of quill drive, similar to that considered in Fig. 2.

Providing that all axlebox springs are similar, or that the axlebox springs associated with the leading and trailing

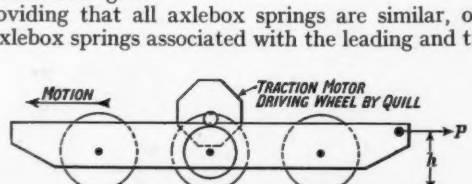


Fig. 4—Three-axle bogie or frame with motor driving through a quill

wheels are similar, the total reaction P_h will be taken on the leading and trailing wheels; thus reaction will be $\frac{Ph}{L}$. If the leading and trailing wheels have dissimilar springs the result is more complex. Consider the case of an axle-hung motor on the centre wheels. This arrangement is represented in Fig. 5. The actual wheel torque PR must be balanced by the couple FD. Thus $F = \frac{PR}{D}$. Now the force F on to the frame is divided amongst the three axles,

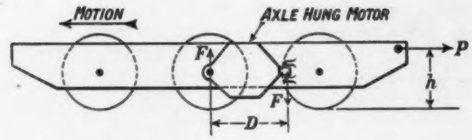


Fig. 5—Three-axle truck or frame with nose-suspended motor on centre axle

and the division depends on the wheel springing as well as the distance D. Assume that the springs are all similar, as would generally be the case, and let the components of F on the axles be F_1, F_2, and F_3 in order from the forward end. Then:

$$F_1 + F_2 + F_3 = F \quad \ldots\ldots \quad (a)$$

$$F_2 \times \frac{L}{2} + F_3 \times L = F \times \left(\frac{L}{2} + D\right) \quad \ldots\ldots \quad (b)$$

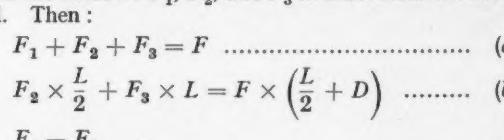
$$\frac{F_2 - F_1}{F_3 - F_1} = \tfrac{1}{2} \quad \ldots\ldots \quad (c)$$

Equation (a) is obtained from considering total vertical forces; equation (b) from moments about the leading axle; equation (c) from consideration of the similarity of the axlebox springs and their deflections caused by F_1, F_2, and F_3.

Table I shows a simple example worked out on the above principles and with the total wheel reaction resolved into their three components, namely: *A.*—Drag reaction is the weight transfer due to the moment $P(h - R)$. This is independent of the motor suspension and depends entirely on the height of the drawgear above the axle. *B.*—Unsprung torque reaction, which is the wheel torque transmitted direct to the rail in the case of axle-hung motors.

TABLE I.

Drawbar pull P	= 6,000 lb.	Drawbar height h	= 3½ ft.
Wheel radius R	= 2 ft.	Rigid wheel base L	= 16 ft.
Wheel base $L/2$	= 8 ft.	Motor suspension base D	= 4 ft.
Loco. weight	= 30,000 lb.	10,000 per axle.	



1. QUILL TYPE DRIVE TO CENTRE WHEELS.

Drag reaction	—562·5	0	+562·5
Torque reaction	—750	0	+750
Total reaction	—1,312·5	0	+1,312·5

Adhesion efficiency of driving wheels = 100 per cent.

2. AXLE-HUNG MOTOR MOUNTED AS IN FIG. 5

Drag reaction	—562·5	0	+562·5
Unsprung torque reaction	—	—3,000	—
Sprung torque reaction	+250	+1,000	+1,750
Total reaction	—312·5	—2,000	+2,312·5

Adhesion efficiency of driving wheels = 80 per cent.

3. AXLE-HUNG MOTOR AS FIG. 5, BUT DIRECTION OF MOTION REVERSED

Drag reaction	+562·5	0	—562·5
Unsprung torque reaction	—	+3,000	—
Sprung torque reaction	—250	—1,000	—1,750
Drawbar reaction	+312·5	+2,000	—2,312·5

Adhesion efficiency of driving wheels = 120 per cent.

C.—Sprung torque reaction, which is the wheel torque reaction transmitted to the rails through the axlebox springs. In all cases an increase in weight is regarded as positive and a decrease in weight is regarded as negative.

Conclusions

Weight transfer in the ordinary four-wheel vehicle may be based directly on drawbar reaction without considering complicated components or method of mounting the motors. In a double-bogie locomotive where the bogies are situated close together the vertical components of the king pin seatings due to a component of drawbar reaction must first be calculated, and then the horizontal king pin forces treated as ordinary drawbar reaction. Again no account need be taken of the method of mounting the motors. In a motor-coach the vertical components of drawbar reaction on the king pins may be neglected and the drawbar pull assumed to react at king pin seating.

In the case of three-axle locomotives or three-axle bogies it is essential to consider the method of mounting the motors, and the method of springing the wheels, together with any form of equalisation. In many cases it is essential to consider the three components of draw-gear reaction (see Table I). It is evident that in the case of three-axle bogies on locomotives the direction in which an axle-hung motor is suspended affects the adhesion efficiency. It can be shown that for certain wheel arrangements using axle-hung motors the motor can be suspended in such a direction that for both directions of motion 100 per cent. adhesion efficiency is available. Such a method, however, will often introduce unpractical features or result in giving the bogie bad riding properties by increasing the horizontal moment of inertia. For this reason motors should not be hung with their mass outside the wheelbase, as has been suggested.

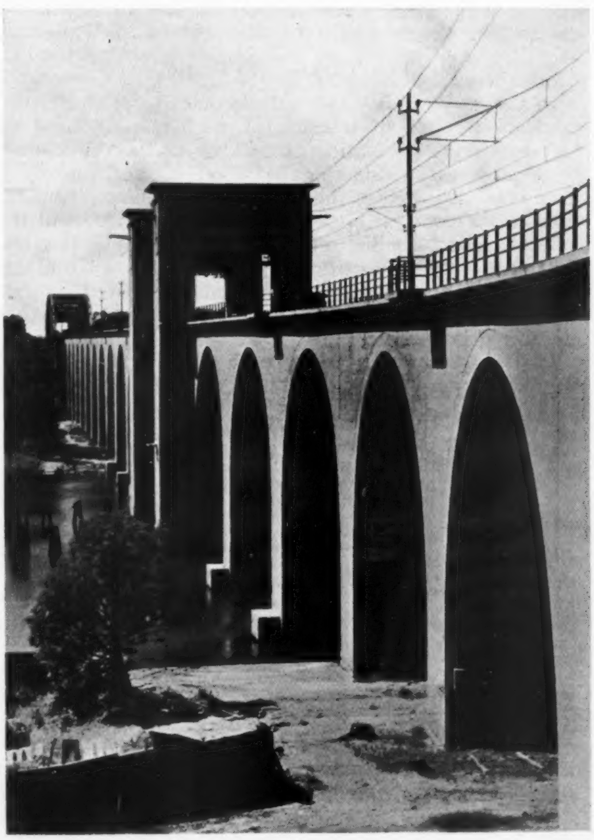
The importance of neutralising weight transfer by pneumatic means, whereby locomotive weight is automatically transferred, or by automatic electric control of the motors, whereby the motor torque is proportional to the available adhesion, is readily appreciated.

Lift Bridge Operation on Electrified Lines

A description of the electrical control for the lift span of the longest railway bridge in Sweden

ONE of the most interesting features of the great Årsta bridge, outside Stockholm on the electrified western main line of the Swedish State Railways, is the vertical-lift span over the fairway towards the northern end. This lifting section has a span of 75½ ft., and in its normal position gives a clearance of 70 ft. above water level. The Baltic, it should be remembered, is tideless. In the lifted position, clearance is increased to 105 ft., so that the lift accounts for a difference of 35 ft.

This lift span is placed between two towers which contain the counterweights balancing the span. In a special machine room in the span itself are installed the lifting and locking machinery. Lifting is effected by two electric motors, each developing 32 h.p. at 650 r.p.m. with 440 volts. Cylindrical gearing connects these to a shaft running throughout the length of the span. At each end, bevel gears transmit the power to a transverse shaft carrying pinion wheels which engage in vertical racks fixed in the masonry of the towers opposite to each corner of the lifting span. For emergency operation a hand crank is fitted to the lifting gear, whereby the span may be hoisted by four men in 60 min. should the electrical supply or machinery fail. Under normal electric operation, the span can be raised or lowered within 90 sec.



The Årsta bridge, showing the lift span, and in the background, the steel cantilever span at the southern end

Current Supply

Current for the motors is taken from the traction supply at 14-16,000 volts 1,623 cycles, single-phase, and stepped down by two single-phase transformers mounted on the outside of one of the towers; only one of these is in use at a time, the other serving as a standby. On the secondary side of the transformers are tappings for 115, 200, and 400 volts. A vertical motor-generator set in the control room converts the single-phase supply to d.c. It consists of a single-phase motor fed from the 400-volt tapping, and developing 52 h.p. at 950 r.p.m.; it is provided with a starting phase fed from the 200-volt terminal. This starting phase is automatically cut out of circuit as soon as the motor reaches its full speed. The motor is coupled to a 30-kW. generator, having its exciter on top; the voltage can be varied from zero up to 460. The exciter, which supplies current to the lifting and locking machinery and to the field of the generator and the brake magnets, is supplied from the 115-volt

Electrically-hauled freight train crossing the lift span of the Årsta bridge, at Stockholm

terminal and can produce 4 kW. at that pressure. The 115-volt terminal also supplies the signal and indicating lamps.

Braking and Locking Arrangements

Double security is provided for the braking and locking equipment. Two shunt-wound brake magnets are provided, one to each motor, and these automatically lift when current is supplied to the motors and fall when this supply ceases. In addition, there is a safety brake, whereby the bridge operator can bring the span to a standstill instantaneously, and lock it, if necessary, from either the machine room or the control room. On closure, the safety brake is applied and this automatically breaks the circuit of the lifting motor. The locking equipment consists of two wedges each end of the lift span, which bear on rollers in the bridge towers, and their insertion results in the instantaneous downward pressure of the span upon the base plate, at whatever elevation it may be at the time. A motor of 10 h.p. at 650 r.p.m. and 140 volts drives the locking wedges from the machine room by a system of shafts similar to those of the lifting machinery. Mechanism for locking by hand is also provided for use in the event of an electrical breakdown. Electric locking takes place in 10 sec., and hand-locking, by four men, in 50 sec. A complete system of limit and interlocking switches, with contacts immersed in oil against the possibility of ice formation on the contact surfaces, makes possible a semi-automatic action and prevents faulty operation.

Electric colour-light signalling is in operation over this section of the Swedish State Railways, which carries the combined traffic of the Gothenburg and Malmö lines, and this is interlocked with the bridge mechanism in such a way that unless the lift section is correctly set for rail traffic the signals guarding it cannot be set to line clear, the points at each end cannot be set for traffic over the bridge, and the overhead conductor is kept dead. Thus non-electric trains (usually diesels for the Nynäs Railway) are safeguarded as well as the standard State electric trains.

Publication Received

Die Elektrische Lokomotiven der Deutschen Reichsbahn. By Georg Lotter. Deutsches Lokomotivbild-Archiv, Darmstadt, Technische Hochschule. 8¼ in. by 5¾ in. 60 pp. Illustrated. Price RM. 2·25 net.—This book gives in tabloid form the principal particulars of all the electric locomotive classes, about 30 in all, operating on the German section of the Reichsbahn down to the E.18 class, the penultimate express type. Not all of the earlier types, built mainly for the Silesian and Central Germany electrified systems, are illustrated, but all are mentioned. The classes built during the last ten years or so, including the 50-cycle Höllental locomotives, are adequately described and illustrated. In addition to a general description of the design and the work for which it was intended, brief tabular data are given, of which the following is an example: Co-Co freight locomotive, class E.93: electrical and mechanical portions built by the A.E.G.: to haul 1,600 tons up 1 per cent. grade at 50 km.p.h. and 720 tons up 2·25 per cent. at 40 km.p.h.: maximum speed 65 km.p.h.: total wheelbase 12·8 m., bogie wheelbase 4·4 m., length over buffers 17·7 m., diameter of wheels 1·25 m.: oil-cooled transformer of 1,680 kVA. on continuous rating plus 250 kW. heating load: six nose-suspended motors each of 335 kW. on the continuous rating at 45·5 km.p.h. and 385 kW. on the one-hour rating at 45·5 km.p.h.: total output 2,010 and 2,310 kW. respectively; contactor control with 15 notches and fine regulation; gear ratio 1 : 5·37: total weight 117 tons: year of first delivery 1933: described in *Elektrische Bahnen* 1934, pp. 97-100.

SOME INCIDENTALS OF A RAILWAY ELECTRIFICATION SCHEME

*By W. J. ENGLAND, Assistant Superintendent of Operation, Southern Railway**

THE incidental works which become necessary through an electrification scheme arise from three causes:—

(1) The actual change in motive power and methods of operation, (2) the altered nature of the service provided, (3) the need for dealing with the anticipated increased passenger traffic.

The practice of the Southern Railway when an electrification scheme is under consideration, is that the section to be electrified is carefully surveyed by means of a series of walkovers; responsible representatives of each of the departments concerned actually walk along the railway to decide the alterations in fixed equipment, and the cable routes for the transmission of both high-tension and low-tension current between the grid and railway substations, and railway substations and track feeding points respectively. The alterations to fixed equipment comprise such items as lay-out, including the elimination of any track connections which may become redundant; signalling alterations; berthing accommodation; platform lengthenings (with any track alterations in connection therewith); conductor rail location and protection; and review of conditions at level crossings and intermediate sidings.

Alterations in Track Layout

At certain stations it is necessary to carry out extensive alterations in the general lay-out. This course may arise at junction points in connection with the break-up and make-up of electric trains to serve divergent routes. Electric working very greatly facilitates the joining up of trains, inasmuch as one portion may be run direct on to another portion and the disposal of engines is obviated. The result of this is that it is possible to introduce a greater measure of through working, which in itself is attractive from the public point of view.

An instance where to meet this contingency it has been necessary to make considerable alterations in the lay-out involving heavy structural works is in connection with the scheme to be introduced in July next for the extension of electrification to Gillingham (Kent) and Maidstone East. The proposal is that trains from London *via* Swanley shall have a portion for Gillingham and one for Maidstone East to divide or join up as the case may be at Swanley. The original lay-out at Swanley was such that the junction was at the wrong end of the station. Therefore it was necessary to alter the position of the station itself so that the junction could be sited at the country end, thereby involving complete rebuilding. Four tracks are being provided through the station in order to facilitate the working of heavy fast steam Kent Coast traffic which has to be dealt with over the route, particularly at summer week-ends.

At many stations, platform lengthenings have to be considered, particularly at stations in the outer suburban area and beyond, where, owing to the changed conditions, the accommodation under steam conditions has become inadequate. A desideratum is to provide platforms of standard length to accommodate the longest trains which will call at the station in question. For physical reasons this cannot at all times be carried out without very considerable expense, for example, when the re-construction of road over- or under-bridges may be necessitated. When such extensions of platforms are made they are usually carried out by the use of pre-cast concrete sections together with pre-cast wall blocks and coping stones, the space behind being filled in with rubble and spoil, the whole then being surfaced with tarmac. Further, in considering an electrification scheme and the prospects of improved traffic, opportunity is taken to modernise station buildings to bring them up to modern requirements. At each station stopping marks showing the points at which trains of varying formations are to be brought to a stand have to be provided.

The introduction of electric running necessitates considerable adjustments to the messroom accommodation for the train staff. The altered conditions incident to an electric service frequently involve a re-arrangement of the points on which motormen and guards are based, with the result that such accommodation as may have been available particularly for steam drivers at running sheds is unsuitable under the new conditions.

Consideration has to be given to the provision of berthing facilities and car sheds, having in mind the necessity of berthing the stock at such points as will ensure car mileage being reduced to a minimum. When car cleaning sheds are erected, particularly in the London area, inspection pits are provided so that inspection, brake block renewal and other light repairs can be carried out during the time the stock is immobile in the middle of the day.

In the case of fog-signalling, in order to give a suitable space for the fog-signalman to work in safety, the conductor rail is, where practicable, placed in the 6 ft. way. If this is not possible, a detonator placing machine is installed and the rail guarded by protection boarding. Similarly, at accommodation, occupation, and footpath level crossings, a break is made in the conductor rail for 9 ft. each side of the crossing, continuity being maintained by means of a buried cable; the gap is reduced in size at public road level crossings as effective protection is provided to users by the gates when closed across the railway.

Signalling Work

The traction current used in connection with the electrification schemes particularly under review in this paper is low voltage d.c., and this entails the conversion of all existing d.c. track circuits to a.c., with the attendant work of installing impedance bonds at the ends of each double-rail track circuit to give the necessary continuity to the running rail return for traction current. Where track circuits cover points and crossings, one running rail only is used for traction purposes and the other is used for traction current return. Where there are no points and crossings, both rails are used for traction current return and double-rail track circuits with impedance bonds are installed. The impedance bonds contain a heavy copper coil so arranged that, while the traction return current can pass the insulated block joints, the a.c. track circuit current is prevented from doing so.

The running of a more intensive service involves the examination of signalling sections throughout the route to be electrified, and their equalisation as necessary to permit a comparatively close headway service to be operated. In certain instances this can be done to some extent by the re-positioning of existing signals; in other cases it is necessary to split the sections by the introduction of intermediate block home signals where only one division of the section is necessary, or where still closer headway is to be worked, by the institution of automatic

* In a paper read before the Institute of Transport, April 3

A typical station rebuilding in connection with electrification—Horsham station, Southern Railway (during the electrification of the Mid-Sussex lines)

signals. Examples of re-positioning existing signals are the placing of the home signal at a greater distance ahead of the signalbox so that earlier acceptance of following trains may be permitted, or the re-positioning of advanced starting signals so that a train may proceed a greater distance on its way while the signalman is waiting acceptance from the box ahead.

The electrification of a line necessitates the installation of separate telephone circuits to enable speedy communication between all passenger stations and the control room or substation governing the supply of current to the conductor rail, so that the current can be cut off in an emergency, or when isolation of sections of track is required in connection with engineering works. All existing telephone circuits have to be overhauled and metallic return provided to overcome noise induction which would result if earth return circuits were still employed. The wires have also to be cabled clear of the high tension switchgear at the substations.

Facilities for Freight Working

The more intensive passenger service presents difficulties in the working of freight trains owing to the absence of suitable train paths for them. It is necessary to run a certain number of freight trains during the day time and in order that they may be kept clear of passenger services it has been necessary in some instances to provide additional refuge sidings with facing connections into them, in order to provide a rapid clearance of the running lines.

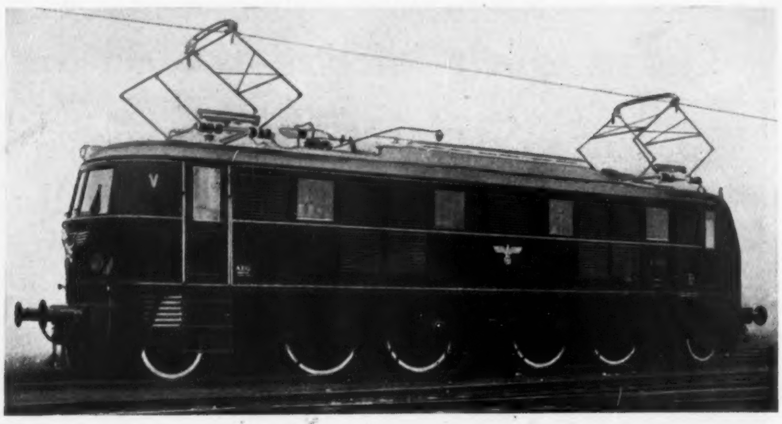
Particularly outside the inner suburban area, there is a surprisingly large number of occupation and accommodation crossings, and public footpaths, all of which require individual consideration. In reviewing these, close inquiry is made into their status, and in instances where a crossing has fallen into disuse, or is rarely used, steps are taken towards its possible elimination. Where crossings are heavily used for the transfer of cattle from one side of the line to the other, in addition to the provision of cattle guards, telephones are installed to enable persons desiring to use the crossing to ascertain from the nearest signalbox that it is safe for the line to be crossed.

Coasting Boards

To assist motormen in so managing their trains as to maintain schedule with a minimum consumption of current, coasting boards, consisting of a white diamond carried on a post, are provided as an indication of the point at which current should be cut off. Owing to the increased frequency of the service, the man-holes in tunnels, the width and condition of the cess, and the position of refuges on bridges and viaducts, have to be reviewed. Other matters that require attention include the insulation of gas or petrol pipes passing under, or alongside, the railway to avoid any risk of fire, improved drainage of the permanent way where there is any danger of flooding, the provision of sandbins on bridges with timber decking, and the issue of insulated tools to the permanent way staff.

During the period the work is being carried out a committee of representatives of each of the departments concerned in the scheme meets regularly to review progress, it being necessary that there should be the closest cooperation between all concerned to ensure that each stage of the electrification scheme, irrespective of the department concerned, is completed at such a time as to enable the ensuing stages to follow on according to programme so that the scheme may be ready by the opening date envisaged at its commencement. The committee concerns itself with such matters as the substation building programme, signalling supplies, permanent way alterations, station alterations, and trial running dates.

High-Power German Express Electric Locomotive



Biggest development of the 1-Do-1 type

THE latest German express electric locomotive for the 15 kV. single-phase lines, the E.19 class, has already been mentioned in these pages (see p. 1, January 6, 1939, issue), but additional dimensions and particulars are given below. The four twin-armature motors have an aggregate output on the continuous rating of 5,030 h.p. at 100 m.p.h., with a corresponding rail tractive effort of 18,480 lb.; on the one-hour rating the output is 5,420 h.p. at 100 m.p.h., with a rail tractive effort of 20,000 lb.; the 15-min. rating is 7,500 h.p. at 84 m.p.h. with a tractive effort at the wheel rims of 33,000 lb. A short-time output slightly exceeding 8,000 h.p. is possible. Of the 1-Do-1 wheel arrangement, the E.19 locomotives have a total weight of 114·5 *tonnes* and an adhesion weight of 80 *tonnes*. The driving wheels have a diameter of 63 in. and the truck wheels 43 in.; the total wheelbase is 42 ft., the overall length 55 ft. 6 in., the height to the crown of the roof 14 ft. 1 in., and the maximum width 10 ft. 2 in. Where track conditions and operating regulations allow, a top speed of 112 m.p.h. can be maintained with an eight-car 360-*tonne* train. Two of these locomotives are now in traffic.

Notes and News

Southern Suburban Stock.—The first of the new six-a-side suburban multiple-unit trains are now in service on the London-Sevenoaks section.

Paris A.R.P.—About 25 stations on the Paris Metro are being modified to suit them as bomb-proof air-raid shelters, at a cost approximating to £1,500,000.

Overhead Line Vibrations.—A paper, entitled " Vibration of Overhead Line Conductors," was read before the Institution of Electrical Engineers on April 12, by Messrs. E. W. Double and W. D. Tuck. It forms a résumé of available data on the causes of and remedies for wire failures in conductors subject to the eddy vibrations due to steady winds ranging from 5 to 25 m.p.h.

Belgian-Dutch Conversion Proposals.—It is understood that discussions have recently taken place between representatives of the Belgian National and Netherlands Railways on the possibility of electrifying the Dordrecht-Antwerp line, and thus providing electric services between the Dutch and Belgian capitals. The existing electrified systems on both railways are at 1,500 volts d.c.

Swedish Electrification.—Electrically-hauled services over the Ånge-Östersund section of the northern main line of the Swedish State Railways were inaugurated during the month of April. The conversion work on the Gothenburg-Åmål section of the Bergslagen Railway is now quite completed, and an electric service is in operation. A full electric passenger service is due to begin on May 15 and the freight service will be turned over to electric traction later in the year. With the electrification over the Ange-Bräcke-Långsele, Bräcke-Östersund and Göteborg-Uddevalla section, scheduled for the end of this month, 84 per cent. of the traffic of the Swedish State Railways will be worked electrically. The estimates for the electrification of the Långsele-Boden section were 28·2 million kr., but according to the latest calculations the cost of conversion has risen to 33·61 million kr. The latest proposals for electrification cover the conversion of the Långsele-Vannas line by October 1, 1941, and of the section from Vannas to Boden by May 1, 1943.

Light Driving Bogies.—Constructional progress in France has resulted in the weight of a complete motor-coach bogie with two traction motors of 180 h.p. each on the continuous rating, and 240 h.p. on the one-hour rating, being reduced to 7 metric tons. The motors in this case are entirely springborne.

Electro-Magnetic Tube.—Powerful magnets arranged at intervals along a narrow gauge track, and which would attract the train successively, have been proposed by a French engineer as the propulsive agent for a special tube railway to connect Le Bourget airport with Paris, and thus improve the carriage of mails which now takes almost as long as the time between Croydon and Le Bourget.

Further Belgian Electrification. — The existing double-track steam main line between Brussels and Antwerp is being electrified on the 3,000-volt d.c. system, and an electric service will begin in October next with one express train, two semi-fasts and two stopping trains an hour in each direction. The present electric service over the parallel route, converted in 1935, apparently is to be retained. Eight new two-car electric trains are being built, electric signalling is being installed, and various stations built or rebuilt in connection with the work.

Improved Train Services, Metropolitan Line, L.P.T.B.—Since March 27 two important changes have been made affecting the Metropolitan Line train services. One is a preliminary to the projection later in the year of Bakerloo tube trains to Stanmore, and consists in the working of Bakerloo stock on the shuttle service between Wembley Park and Stanmore. The other is the placing in through service between Barking and Rayner's Lane, via Aldgate East and Baker Street, of 8-car trains of the newest type of stock, with air-worked doors. A total of 21 such trains is on order for this service, and will replace the existing Metropolitan 6-car trains.

Electric Railway Traction

Electrification Progress

RAILWAY electrification throughout the world in general has followed three phases. First, the conversion of suburban lines and short distance routes where long or many tunnels caused a smoke nuisance. Secondly, the conversion of mountain-grade lines. Thirdly, the conversion of lines of a more level contour carrying heavy and dense traffics. Within the first category come the Hoosac tunnel on the Baltimore & Ohio Railroad, the Quai d'Orsay—Austerlitz tunnel in Paris, the Simplon tunnel, the Mersey Railway, the urban and suburban lines in London, Merseyside, Tyneside, Berlin, Paris, and Milan. In the second stage are the St. George de Commiers-Le Mure line (1904), Guaqui-La Paz, Lötschberg, Mariazell, and Giovi lines, all pre-war conversions, and the Gotthard, Ujo-Busdongo, Rhaetian, Austrian, Chicago, Milwaukee, St. Paul & Pacific, Turin-Modane and Chambery-Modane lines in the war or post-war years. Finally, in the third section are the P.O. main line, the German main lines in Silesia and Bavaria, the Japanese Tokaido route, the Stockholm-Gothenburg line, and the Pennsylvania system between New York, Washington, and Harrisburg. In the hydro-electric power countries, more particularly Switzerland, Sweden, Norway, on the ex-Midi Railway in France, and in Italy, the fuel question decided the question of electrification, and although as a rule the lines with the heaviest traffic were converted at an early stage, they did not generally carry traffics which would have been counted heavy in a big industrial area. Mountain line conversions to d.c. have become more frequent since practicable and economical regeneration was evolved (*e.g.*, Natal, Algeria, and the G.I.P.) but there is, and must surely continue to be, an increasing proportion of conversions due solely to the benefits which electric traction brings for the operation of heavy traffic, for example the Nuremberg-Halle line of the Reichsbahn, the first section of which was opened on May 15, and the Manchester-Sheffield line on the L.N.E.R., conversion work over which is well in hand.

Electric Traction in South Africa

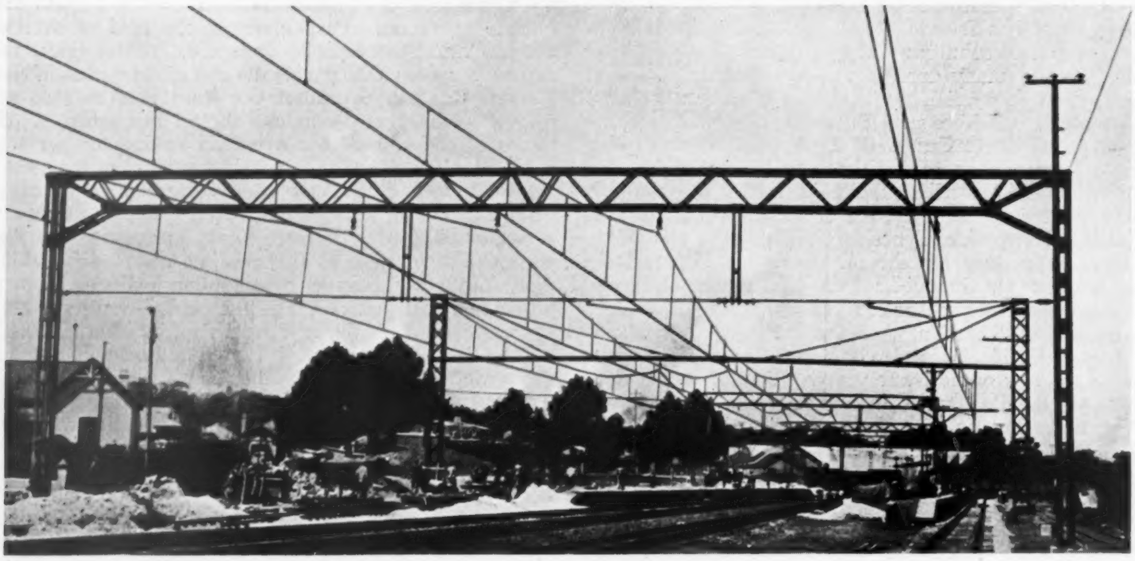
WITH electric operation now in full force over the Reef lines, the electrified route mileage of the South African Railways has risen to about 555 and the equivalent mileage of single track to approximately 1,075. The conversion cost of the Reef lines, comprising 130 route or 330 track miles, was about £1,150,000 neglecting the credits for serviceable steam locomotives released for duty on other lines, this amount being considerably less in proportion than the cost of the early Natal and Capetown conversion schemes. Electric traction in South Africa was inaugurated about 15 years ago under most unpropitious circumstances; the estimated cost of conversion was heavily exceeded, a trade depression began shortly after the first opening, and the extremely severe lightning storms in Natal caused considerable damage to the electric locomotive and stationary equipment. The initial experiences with electric traction were such as to prejudice seriously the prospects of extensions, and the high cost of energy, due in part to the necessity of building new power stations for the Natal and Capetown schemes, did nothing to alleviate the position. But the operating advantages of electric trains were realised to be of such magnitude that the railway staff carried out many investigations over a period of years with a view to cheapening the capital cost of any extensions, as well as to gain more reliable operation. Particularly in the field of overhead construction for the 3,000 volts d.c. contact lines, their success was such as to enable the cost of extensions in Natal and the Cape to be undertaken from 1931 to 1935 at a fraction of the cost per mile of the original schemes. For example, the cost of the overhead equipment per track mile was about £1,350, only half the figure of the 1924-25 conversions, and the cost of a substation was reduced from £42,000 for a single-unit rotary plant to £11,000 for a single-unit rectifier plant. Again, no new power plant was necessary, and as the existing plants were utilised more fully and the power consumption increased, both the production cost per kWh and the capital charges per unit decreased, and for the new Reef electrification the cost of current is well below ½d. per unit, although in this case the power is being bought from a private undertaking as well as from the Electricity Supply Commissioners. Incidently, no railway-owned h.t. transmission line was necessary. It was the intention at first that only the suburban and local passenger trains on the Reef should be electrically-operated, but the advantages of eliminating the maximum possible number of steam locomotives from the area, in addition to other operating benefits, have caused electric locomotives to be introduced for a great portion of the freight traffic.

Electricity at the Swiss Exhibition

CONSIDERING the size of the exhibition both electricity and electric traction are well represented at the Schweizerische Landesaustellung now being held at Zurich, and open until October 29, as might be expected from a nation that has done so much to advance the science of electric railway engineering and hydro-electric power generation. The principal railway exhibit is the 12,000-h.p. single-phase Oerlikon locomotive for the Gotthard line of the Swiss Federal Railways, which was illustrated and described in the issue of this Supplement for February 3 last. 100 tons less in weight, and of just half the power output, is the 1–Co+Co–1 express locomotive for hauling heavy trains over the Lötschberg route (Brigue-Spiez) of the Berner Alpenbahn Gesellschaft. This, also, is quite a new locomotive, although other locomotives to the same general design have been in service for some years. Sécheron electrical equipment and individual axle drive are incorporated. The single-unit Red Arrow motor-coach of the Federal Railways has been developed into a twin-unit non-articulated set, complete with buffet, and the first of these new twin-car formations is on show, end-to-end with one of the twin-car articulated electric trains of the Berne-Neuchâtel Railway. (See issue of this Supplement for December 9, 1938.) Access can be gained to the interior of all these locomotives and trains. In the electrical section there is a large array of rectifier installations, including a grid-controlled glass-bulb set, oil-cooled three-phase transformers, motors, relays, meters and the like, and also very complete information about the Swiss hydro-electric stations and h.t. transmission systems, including a large model of one of the generating stations with its catchment area, lakes, and barrages.

THE REEF ELECTRIFICATION

Suburban and short-distance passenger traffic of great magnitude is now operated by high-tension d.c. electric traction, and has increased by 25 per cent. since conversion



Layout of 3,000-volts d.c. overhead equipment at Tooronga station

THE phenomenal expansion of the gold-mining industry on the Witwatersrand following the abandonment of the gold standard by Great Britain in 1932 resulted in a considerable increase in suburban traffic, as well as in freight traffic, in the Pretoria-Johannesburg area, and in 1935 the electrification of the Randfontein-Springs line and certain offshoots was approved as far as suburban passenger train operation was concerned, thus reviving a project which had been considered first in 1903, again in 1912-14, and then definitely recommended in the Merz & McLellan report of 1919. The scheme was subsequently enlarged to include the Germiston-Pretoria line, and as recently completed covers the conversion to the 3,000 volts d.c. system of 130 route miles, equivalent to 330 track miles.

Electric traction for the suburban passenger traffic was introduced on the Germiston to Alberton and Wattles lines on March 15, 1937; from Johannesburg to Springs and from Apex to Welgedacht in June, 1937; from Johannesburg to Pimville in September, 1937; and between Langlaagte and Randfontein on January 31, 1938. The conversion work on the Germiston-Pretoria line was somewhat delayed by track realignment and improvements, and electric traction was not introduced until December, 1938.

With the complete scheme now in operation the current consumption is in the neighbourhood of 100,000,000 kWh a year for traction. The power cost is thus a vital factor in the economic success. In the early days of electric traction in Natal and in the Capetown area the cost of current was as high as 0·897d. and 1·25d. per kWh respectively, partly owing to the necessity of erecting special power stations, at Colenso and Salt River. Due to increased consumption following various extensions of the electrified lines, the costs in these two areas today are 0·58d. and 0·74d. per kWh respectively, but for the Reef lines the current is being obtained from outside sources, and the cost at the d.c. busbars with the present estimated annual consumption will be about 0·4d. per kWh.

Power Supply and H.T. Distribution

The power for the Reef electrified area is being drawn from the joint distribution system of the Victoria Falls & Transvaal Power Co. Ltd. and the Electricity Supply Commission. These two authorities supply most of the mines, industries, and towns in the area and jointly own or operate a number of large power stations. The installed capacities of those belonging to V.F.P. are:

Vereeniging	139,500 kW
Rosherville	60,000 kW
Brakpan	48,000 kW
Simmer Pan	43,000 kW

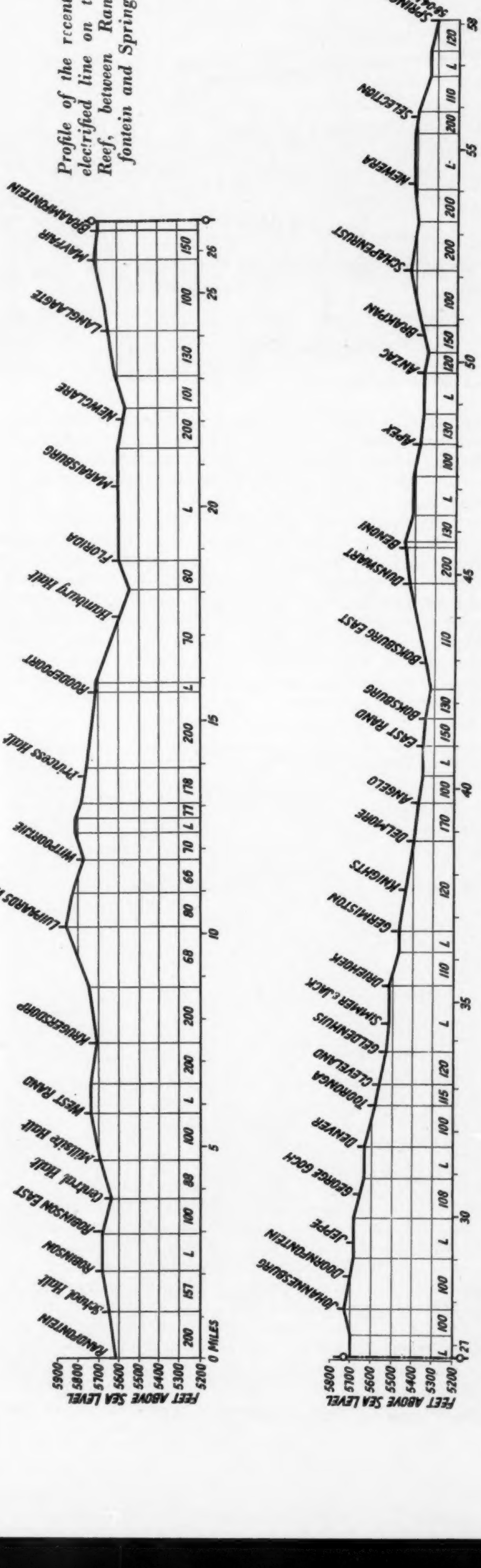
The two power stations in this area belonging to the Electricity Supply Commission but operated by the V.F.P. are :

Witbank	100,000 kW
Klip	350,000 kW ultimate designed capacity

The Reef area is covered with a grid transmission system, and the main distribution line of the V.F.P. extends beyond Heidelberg to the east and to Krugersdorp in the west, so that the provision of a separate transmission line parallel to the railway for feeding the traction substations, similar to those in Natal and the Cape, is not necessary, and traction current is supplied through feeder lines from the main h.t. system.

Railway Distribution System

The high-tension a.c. supply is not the same to all twelve substations, being 40 kV to those at Orlando, Apex, Welgedacht, Selection, West Rand, Roodepoort, Birch-



Profile of the recently electrified line on the Reef, between Randfontein and Springs

leigh, Pinedene, and Pretoria; 20 kV to those at Braamfontein and Booysens; and 10 kV to that at Germiston. The frequency throughout is 51 cycles. The substations contain one, two, or three rectifier sets according to the loads they are required to carry. (See accompanying map). The substations are the property of the Electricity Supply Commission, and the erection of the equipment was carried out on behalf of that Commission by the railway administration.

A 6,600 volts three-phase overhead transmission line is carried by extension masts on the track overhead structures for the purpose of supplying current for station lighting and colour-light signals. This line is fed from a local supply transformer installed at certain of the traction substations, and an emergency low-tension supply taken from this 6,600 volts system is provided in each substation, through suitable step-down transformers.

Substation A.C. Switchgear

The high-tension a.c. switchgear is of the outdoor type, and all main connections are of the solderless concentric grip pattern. The disconnecting switches are of the rotating-post type arranged for manual group operation from ground level, and are provided with locking arrangements for the open or closed positions. They are designed for operation when the line is alive but no current is flowing, and they are capable of carrying a 400-amp. current without overheating. Interlocks are fitted to prevent the operation of any disconnecting switch while the oil circuit breaker in series with it is closed.

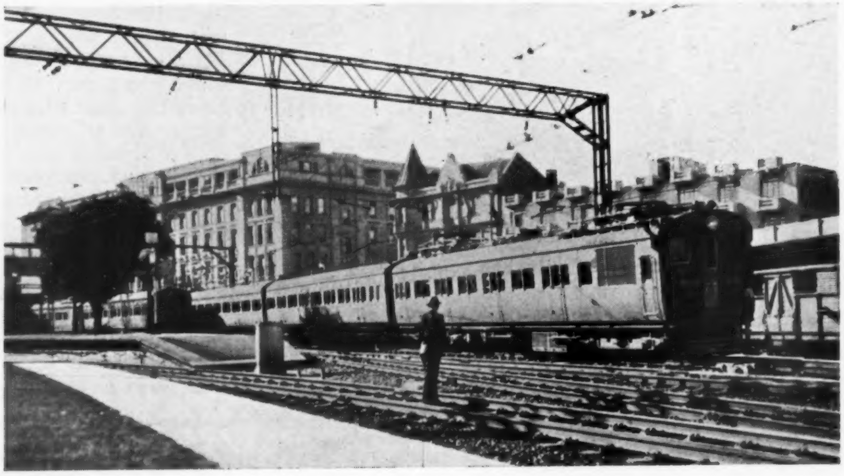
Each oil circuit breaker is capable of carrying a current of 400 amp. without overheating or burning of the contacts, and the temperature rise under fault conditions, measured at the hottest part of the oil, does not exceed 30° C. These breakers are capable of rupturing currents varying from 7,220 to 28,880 amp., according to the location of the substation, on any one, any two, or on all three poles at the rated voltage and at an altitude of 6,000 ft. above sea level in accordance with the following requirements: twice at a two-minute interval, and then to be in a condition to be closed and carry the rated current until such time as it is practicable to inspect it and make the necessary adjustments.

The circuit breaker structures, including the oil tanks, are so designed as to produce no undue strain when interrupting any fault which may occur on the circuit which a track breaker controls, and provision is made for gases generated during operation to be led away from the breaker. The operating and control mechanism is designed to permit of the circuit breaker opening freely immediately contact is made, and so that once an operation has been started it must be carried to completion before any further operation can be initiated, and the design of the breaker itself ensures free action and the reduction of mechanical shock to a minimum.

All breakers can be locked in the open position to prevent inadvertent closing, and mechanical indicating devices are fitted to the breaker to show whether it is in the closed or open position. Each oil circuit breaker is provided with overload protective gear which includes a three-element induction-type overcurrent relay at specified current settings. The protective relays are operated by three-bushing multi-ratio current transformers.

Main Transformers

The main rectifier transformers are of the outdoor oil-immersed self-cooled type, and were designed to come within the loading gauge of the South African Railways, in order to facilitate transport from the coast to the Rand. Each transformer has a three-phase triple star-connected low-tension secondary winding for connection to the



Six-car electric train set leaving Johannesburg for Orlando, 3,000-volts d.c. Reef electrified lines, South African Railways

rectifier set. The neutral point of the primary winding is brought to the outside of the tank through a suitable bushing. A low-tension tertiary winding is provided in each transformer for the operation of the substation auxiliaries.

In order to standardise the plant as far as possible, despite the difference in the incoming h.t. supply at various substations, each transformer has primary windings which can be connected in series or in parallel, so that the same apparatus can be used in conjunction with either the 20 kV or 40 kV supplies. To facilitate the changing of the connections of the primary windings to suit the different supply voltages, all primary connections are brought to a terminal board inside the transformer, above the core and normally in oil, and which is easy of access without the necessity of draining the oil below the level of the top of the windings. The transformers are designed to operate at rated output at any frequency within ± 2½ per cent. of the nominal frequency of 51 cycles a second without the temperature rise exceeding that specified in the B.S.I. No. 171—1927.

As the substations are situated in a district where lightning storms are frequent and severe, the transformer windings were specially designed and insulated to withstand abnormal surge conditions, and the high-tension a.c. supply system is provided with Petersen arc suppressors. Each transformer is fitted with an oil conservator tank and a calcium chloride de-hydrating breather, and also with a dial-type thermometer for registering the temperature of the oil at the top of the transformer; there is also a Buchholz protective relay. Temperature alarm contacts and oil circuit breaker tripping contacts are fitted; the alarm is set to operate at 95° C. and the trip at 105° C.

Rectifiers

The mercury arc rectifiers used are of the B.T.H. steel tank pattern, and unlike those of similar manufacture installed in the Natal section, are not arranged for inverted operation, as regeneration is not contemplated on the Reef lines, where the gradients are not heavy. But grid control is incorporated to suppress arcs in the rectifier tanks due to back-fires or short circuits. Under normal conditions all the grids are floating, but on the occurrence of a back-fire or short circuit a negative bias is applied to all grids to extinguish the arc. The negative grid is obtained from a d.c. generator driven by the motor which drives the rotary vacuum pump and the circulating water pump. Application of the bias to the grids is effected by means of a special high-speed multi-pole reverse current relay operated from a shunt in the rectifier cathode lead. Each grid lead is provided with a current limiting resistance and a surge arrestor as a protection against overvoltage.

A back-fire does not cause the high-tension a.c. oil circuit breaker to be tripped. Only the grid blocking relay and the rectifier d.c. high-speed circuit breaker operate, the latter in order to interrupt the reversing current feed into the rectifier from the d.c. busbars. The grid relay is raised and the high-speed circuit breaker recloses automatically after a short delay when the back-fire arc has been extinguished, by means of a notching-type reclosing relay arranged to operate a predetermined number of times in the event of persistent back-fire, and then to lock out, shutting down the rectifier unit at the same time.

Each rectifier unit is self-contained and operates independently of other units in the same substation. No switchgear is fitted between the transformer and rectifier, the two being permanently connected; wall bushings are provided to carry the six-phase a.c. leads and the transformer neutral leads through the substation wall. However, rectifier units operate in parallel with each other on the d.c. side. Individual rectifier units are designed to carry continuously d.c. loads of 500 amp. at 3,000 volts, equivalent to 1,500 kW, and can carry the following overloads without injury:

Two hours	2,250 kW
30 minutes	3,000 kW
One minute	4,500 kW
10 seconds	5,250 kW

Ignition and excitation anodes and all necessary ancillary apparatus for their control and operation are incorporated, and in view of the nature of the load, viz., a traction load with rapid variations and periods of zero load, special attention was paid to the excitation in order to ensure satisfactory operation of the rectifiers. The ignition anodes are of the solenoid-operated dipping type. Three-phase excitation is provided, and for this purpose three excitation anodes are employed. Ignition and excitation anodes are supplied with a special transformer, incorporated with an insulating transformer, and carrying the necessary control gear on top so that the whole forms a self-contained unit. The ignition and excitation circuits are arranged to operate on the 380 volts three-phase auxiliary supply.

The complete process of ignition takes place automatically as soon as the insulating transformer is made alive on the primary side. Apparatus is provided to enable the

pick-up of the excitation current to be checked before the rectifier is placed on load; the excitation current is about 9 amp. (r.m.s.) per anode. The ignition current is stabilised by reactance. Cooling of the anodes is effected by a ribbed cooler fitted to the top of each anode stem, and cooled by natural draught. The auxiliary electrodes are of the self-cooled type.

The rectifier tanks are water-cooled, and each has a separate closed-circuit equipment comprising a nest of fin-tubes over which air is blown by a motor-driven blower, a centrifugal water pump, and the required piping and valves. The complete cooler is mounted on insulators as it is at the same potential to ground as the rectifier tank, but the blower motor and air pipes are at earth potential. Being driven by the motor which operates the rotary vacuum pump and grid bias generator, the water pump is operated at full speed while the rectifier is in use, but the blower motor is run intermittently and is controlled by a thermostat in the cooling water circuit, so that the time of its operation depends upon the load on the rectifier.

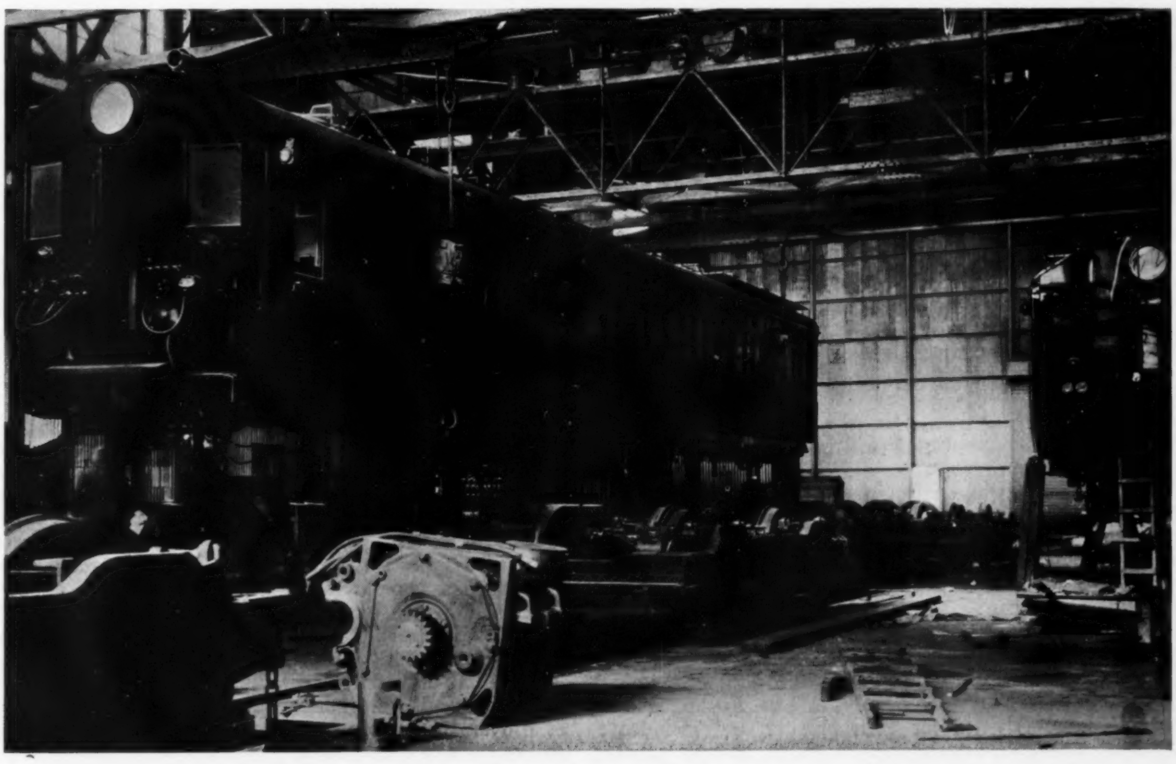
Separate cooling equipment is embodied for the mercury high-vacuum pump; it is similar in type to the main cooler. On shutting down a rectifier the main recooler blower shuts down immediately, but the mercury vacuum pump cooling set continues to run without interruption. The vacuum pumping system for a rectifier consists of a mercury vapour high-vacuum pump, a pre-vacuum receiver, and a rotary pre-vacuum pump connected in series, all mounted on the rectifier tank. The mercury vacuum pump has a high pump speed and is capable of maintaining a pressure of about one micron in the rectifier when working against a pressure of several millimetres. The mercury boiler of this pump is heated by induction, the mercury forming the secondary of a small transformer. The high-vacuum pump is in operation whether the rectifier is in operation or is in the shut down position. A valve is provided on the suction side of the rotary vacuum pump to prevent oil being sucked into the pre-vacuum receiver through the pump when it is shut down. The rotary vacuum pump is run during the whole of the time the rectifier is in operation; it does not stop when the rectifier is shut down, so that the required pre-vacuum pressure can be maintained whether the set is in service or not.

McLeod vacuum and Pirani electrical vacuum gauges are fitted, and the vacuum indicator is supplied with auxiliary contacts for the purpose of operating an alarm in the event of the vacuum in the rectifier tank falling below the predetermined value. The rectifier tanks are fitted with a special arrangement of spray nozzles and splash baffles to break up the streams of condensed mercury flowing back to the cathode. Two annular settling spaces arranged in series are provided in the tanks to settle out dust and other impurities from the condensed mercury as it returns to the cathode pool.

All rectifier auxiliary plant is designed to operate on the three-phase four-wire 380/220 volts supply obtained from the transformer tertiary winding. As the supply from this source is interrupted immediately the high-tension a.c. oil circuit breaker is opened, automatic change-over equipment is installed to disconnect from this supply those auxiliaries which are required to operate after the rectifier has been shut down, and to connect them to a standby obtained from the auxiliary transformer. Immediately the oil circuit breaker is reclosed, these auxiliaries are automatically disconnected and returned.

D.C. Switchgear

A draw-out type of d.c. high-speed circuit breaker is used for the connections in the cathode lid of each rectifier to protect the rectifier against reverse current; inter-



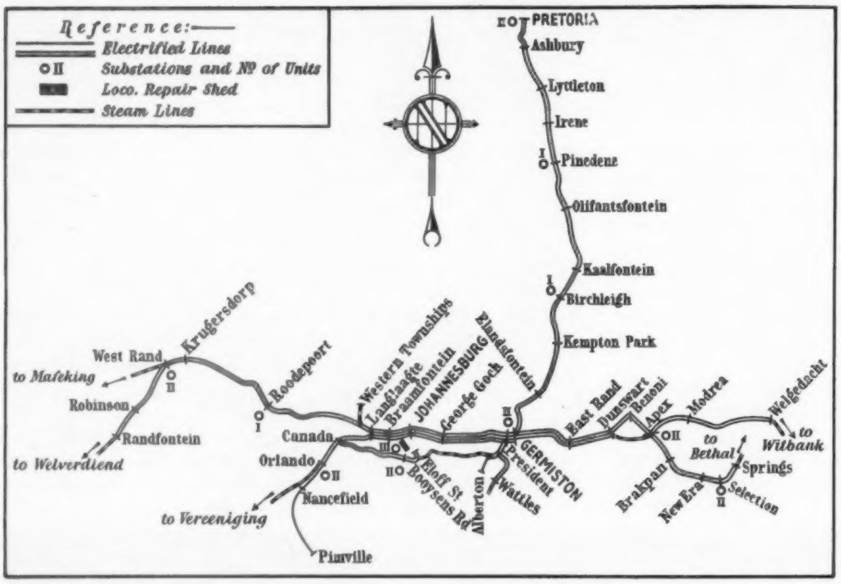
Lowering one of the Reef motor-coaches on to the bogies at Braamfontein depot

locking prevents the circuit breaker from being drawn out while it is operating in the closed position.

Single-bell manually-operated disconnecting switches are provided for the purpose of isolating individual rectifier units from the substation d.c. negative busbar for inspection or repair, and interlocking makes it impossible to operate this switch while its rectifier is in operation. Comprehensive interlocks are fitted on the plant to prevent the possibility of switching operations being performed incorrectly and also to obviate the possibility of the plant being made alive at dangerous or inconvenient times.

Smoothing equipment for the reduction of the harmonics in the d.c. voltage is attached to each rectifier, and comprises an air-cored series coil, four resonant shunt circuits, a discharge resistance, and a h.t. fuse for the protection of the shunt circuits. The series choke coil is connected in the main d.c. circuit between the cathode and the rectifier high-speed circuit breaker. Each resonant shunt circuit consists of an air-cored reactance coil and a condenser connected in series, the four shunt circuits being tuned for frequencies of 306, 612, 918, and 1,224 cycles per sec. respectively. The reactance coil forming part of each shunt circuit is wound in sections connected in series, and so arranged that by altering the relative positions of the two sections the reactance can be varied over a sufficiently wide range to permit of accurate tuning of each shunt circuit within the tolerance limit of the condenser capacity. The discharge resistance is suitable for connecting permanently in parallel with the resonant shunts to ensure that the condensers will be discharged whenever the rectifier is shut down.

The switchgear for controlling the outgoing 3,000 volts d.c. feeders consists of draw-out type high-speed circuit breakers, and at all substations outgoing track feeders are provided, each feeding a separate section of the overhead wire system. The high-speed breakers protect the outgoing d.c. positive feeders from damage due to short-circuit or heavy overload conditions; they are designed for operation on 110 volts d.c. obtained from the substation battery, and are arranged for remote electrical control from nearby signal cabins. A separate remote control panel is fitted for each breaker and includes a position-indicating device and an alarm bell to indicate when the breaker trips. The overhead contact wire system is fed from the substations through positive cables and the substation negative busbars are connected to the track by means of underground cables.



Map of Reef electrified lines, South African Railways, showing number of tracks and the number, location, and capacity of the rectifier substations

Substation Control

The substations are unattended except for periodic visits for inspection and routine maintenance, and starting operations and protective devices are largely automatic. A control panel is fitted in the substations and a separate remote control panel in the nearest signalbox for starting up and shutting down each rectifier unit. These processes from either panel are accomplished in one operation, but it is not possible for the local and remote control systems to be in circuit simultaneously; a change-over control switch is provided on each substation panel to give whichever circuit may be required. Each remote control panel has an indicator to show whether the rectifier is running or shut down, but does not indicate the former position until the set has been connected to the substation d.c. busbars by the closing of the rectifier high-speed breaker. An alarm bell is attached to each remote control panel to indicate when a rectifier has been shut down completely by the tripping of the high-tension a.c. oil circuit breaker. In addition to the control switches, separate operating switches are provided on the substation control panel to enable the high-tension a.c. oil circuit breaker and the rectifier d.c. high-speed breaker to be operated independently if required for test purposes.

Overhead Equipment

In order to bring the cost of the overhead equipment within economic bounds, the technical side of the railway administration carried out extensive experiments with a view to greatly cheapening the construction compared with the costly type which was used in the original Natal scheme. The main factors in the new designs and methods were the use of locally-manufactured pre-cast concrete foundations, masts fabricated from discarded rails and steel sleepers, and a well-organised and efficient system for speeding-up erection. By these means the capital cost per mile of the overhead equipment was reduced to a little over £1,300 per mile of track, or less than half the cost of the original Natal scheme.

A thorough inspection and survey of the section of line

to be electrified was made and rough line drawings prepared on the site. From these complete location plans are made in the drawing office of the Chief Electrical Engineer which indicate the spacing of the overhead steel structures to carry the catenaries. These masts are normally placed about 220 ft. apart but there are intermediate pull-off masts on curves and at points to register the contact wire over the track. When the general survey is complete, details are taken out of the material required and the orders placed.

Some central point is selected for the location of a fabricating depot and the layout is prepared, which facilitates operations and reduces handling to a minimum. Raised skids are erected, comprising old rails supported on the ends of sleepers planted in the ground. Discarded rails received at the depot are stacked direct from trucks on to the skids, ready for use. Along one side of these skids is a rollerway about 2 ft. wide and of a length to suit the particular conditions of the depot; along this rollerway straightening, drilling, cutting, and other machines are installed. In this way the rails drawn from the stocks are made ready for use and passed to the fabrication sheds. The finished steelwork is loaded off the skids ready for erection on site without once being lifted. Moulds are constructed for the casting of the concrete foundations and the necessary reinforcing rod is shaped at the depot.

Steel Mast Erection

As far as possible, the steel masts are manufactured to standard drawings, but they vary in height according to the conditions at the point of erection, being of the minimum height where the contact wire has to pass under low structures, and at the maximum height at level crossings. The masts used for one, two, three, and four-track structures comprise two 60-80 lb. rails welded to batten plates which have previously been drilled for the bolting of bridges and other fixtures. Box-type masts are specified in cases where the bridges are required to span more than four tracks, or where colour-light signalling or other equipment has to be carried.

The location positions of the overhead structures are pegged and labourers set to work excavating holes for the reception of the pre-cast foundations which are loaded into trucks at the depot and distributed along the track as required. By the use of pre-cast blocks the preparation of foundations on site is obviated, and does away with the necessity for distributing sand, stone, cement, and water along the track. The pre-cast foundations are set in the excavations by means of portable tripods and thereafter are ready for the reception of the steelwork. The masts are loaded up in drop-sided steel bogie wagons carrying an average of 40 masts per truck. From 100 to 200 structures are loaded for erection during one occupation of the track, which is usually afforded at the weekends, beginning about midnight on Saturday. Most of the masts are of the two-legged type with one leg about 12 in. longer than the other. In the erection process the longer leg is inserted in the circular aperture provided in the base, but the shorter leg rests on top of the foundation. The mast is erected at right-angles to the top concrete block, in which there is a circular hole through which a bolt passes to secure the mast. A quantity of concrete, which is prepared on a special truck in the train, is used for filling in the space round the longer leg in the base.

During the initial stage of erection the mast is held by a steam crane, but immediately the mast is bolted to the top foundation block the crane hook is released and the train moves forward to the next location. The mast is then held by a hard line while being plumbed, and the portion below ground level is tarred; thereafter the foundation excavation is filled in with soil, thus burying the two concrete foundation blocks. The cantilever arms, or the bridge girders in the case of multiple-track structures, are then erected, after which the wiring operations are begun. Pulley blocks are attached to the steel structures and catenary wire is attached to these as it is paid out from drums mounted on the wagons, which are pulled by an engine at a speed of about 5 m.p.h. After the catenary has been run out the droppers are attached and then the contact wire is run out in a similar fashion to the catenary. After the fixing is completed the overhead assembly is tensioned and positioned and the insulators erected.

Multiple-Unit Trains

The original contracts in the rolling stock section comprised, as far as electrical apparatus was concerned, 72 four-motor, 1,500-3,000-volt multiple-unit equipments with one driving position; 32 trailer equipments with one driving position; and 128 non-driving trailer equipments. Subsequent contracts increased these totals to equipment for 119 motor-coaches, 80 driving trailers, and 235 non-driving trailers. All these equipments were not installed in new stock, the trailers being rebuilt from steam stock by the South African Railways. The motor coaches and certain driving trailers, generally of steel construction, were ordered from the Metropolitan-Cammell Carriage & Wagon Co. Ltd. and the Birmingham Railway Carriage & Wagon Co. Ltd. Certain motor-coaches have first class accommodation and the others third class, and in both types the seats are arranged in open saloons. The bogies have a wheelbase of 8 ft. 6 in. and are pitched at 41 ft. centres. Timken roller bearing axleboxes are used. The average tare weight of the motor coach is about 56¾ tons and the total weight of a six-coach train in the fully loaded condition about 275 tons. A six-coach train is powered by eight American General Electric traction motors with an aggregate one-hour h.p. of 2,500. A complete description of the electrical equipment of the multiple-unit stock was given in the issue of this Supplement for February 3, 1939.

Passenger and Freight Operation

The greater speed and shorter running times already achieved by electric trains on the Rand during the year the service has been in operation are indicated by the fact that there are now 25 and 30 trains each weekday on the Johannesburg-Randfontein and Johannesburg-Springs lines respectively, compared with 18 and 27 steam trains in 1937. On the Johannesburg-Pimville section 27 trains run at present as against 20 steam trains. On Sundays each of these routes carries four trains more than in the years of steam traction. The saving of time ranges from a minimum of 11 min. on the Johannesburg-Springs fast service, to a maximum of 20 min. on the all-stations Pimville-Jeppe line. The trains stopping at all stations between Johannesburg and Springs now complete the journey in 70 min. compared with 85 min. by steam; the fast trains occupy an hour, or 11 min. less than by steam. All-station trains from Johannesburg to Randfontein now take 63 min., 19 min. less than formerly, and the fast train covers the journey in 55 min.

Electric operation of freight trains is being introduced between Braamfontein, Germiston, and Pretoria. The section from Pretoria, and including Pretoria West yard, to the yards at Germiston, Braamfontein, and Pretoria and the various sidings and interloops along the route have been installed with the necessary equipment. The section of the Rand mineral line between Canada and Village Main is also to be electrified shortly for passenger traffic, consisting exclusively of natives from the locations at Mlamlankunzi, Orlando, Nancefield, and Pimville.

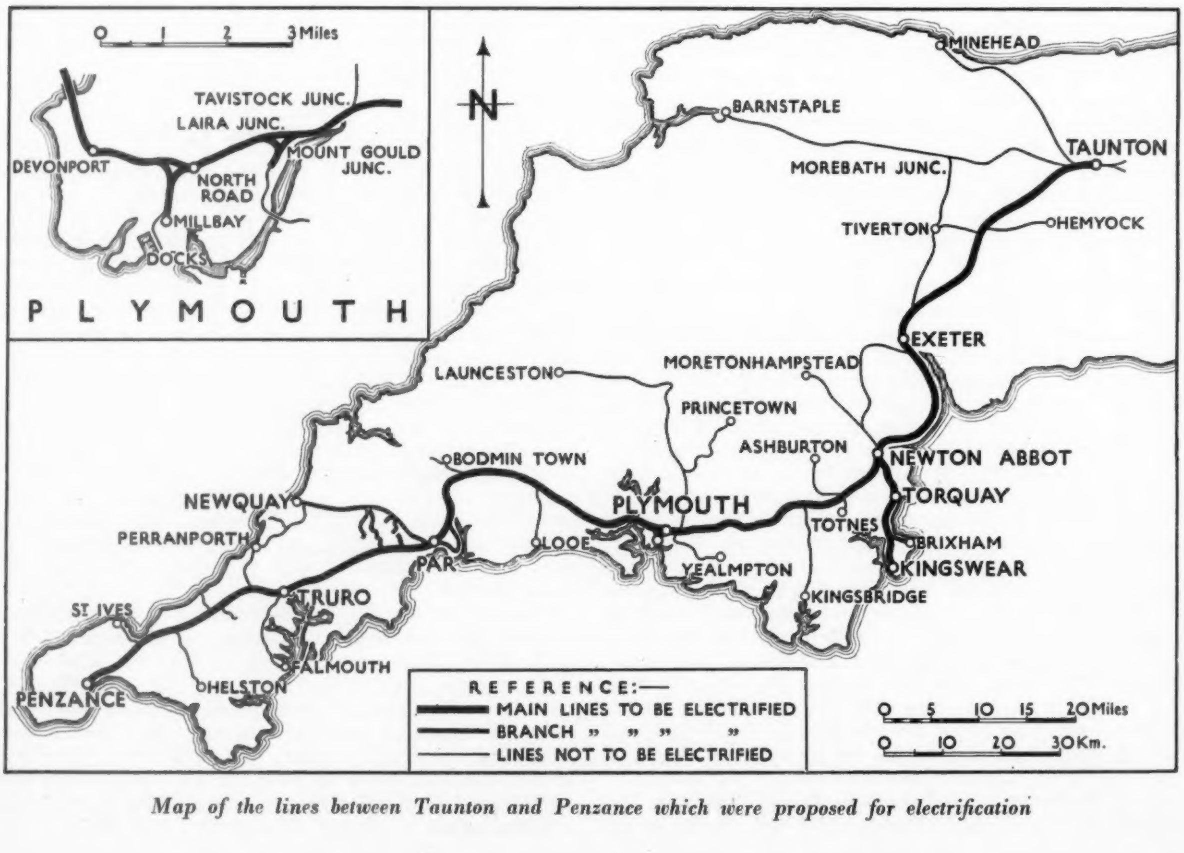
THE GREAT WESTERN RAILWAY AND ELECTRIFICATION

Estimated costs and results of the Taunton-Penzance scheme as given in the Merz & McLellan report

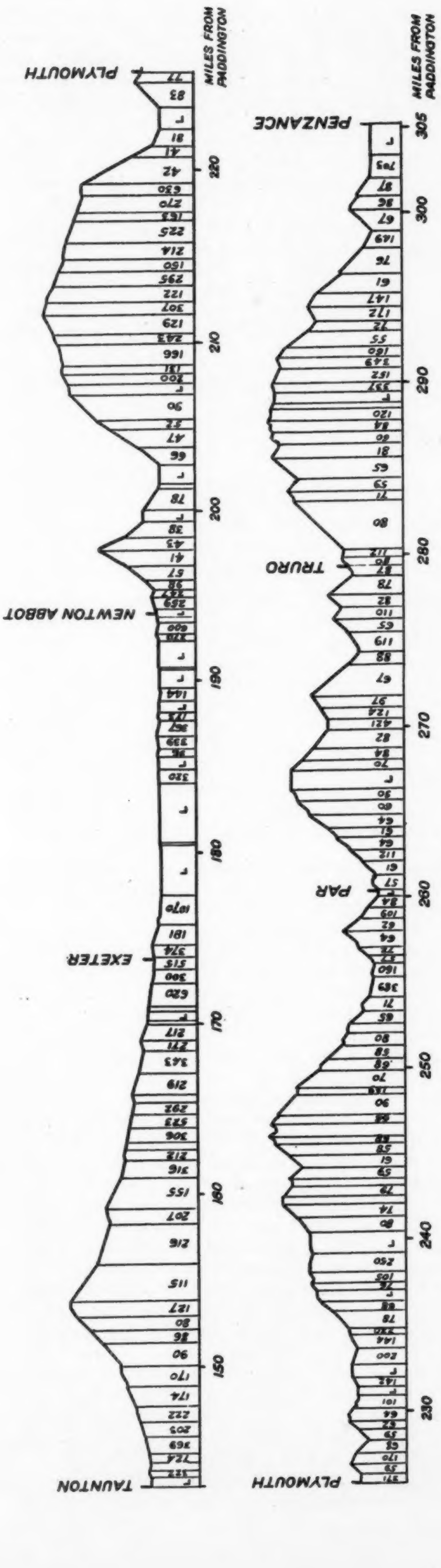
As we announced in the columns of The Railway Gazette last week, the Great Western Railway has decided not to proceed with the project for the electrification of the main line between Taunton and Penzance and the branches connected thereto. We are able to reproduce, by the courtesy of the railway company, tables setting out the estimates made by Messrs. Merz & McLellan, the consulting engineers, of the capital expenditure involved in the scheme, the annual working costs by steam and electric traction respectively, and the capital charges on the electrification expenditure, showing the estimated balance of saving in working costs which would be available for interest on the net capital expenditure. This, it will be seen, represents a return of only 0·75 per cent., which is in striking contrast to the results being achieved on the Southern Railway, where, as indicated by Mr. R. Holland-Martin, the Chairman, at the annual general meeting of that company in February last, a net income has been earned largely in excess of the interest required to cover capital expenditure in every area where they had changed from steam to electric working. A predominant consideration on the Great Western Railway is that the bulk of the traffic over the Taunton—Penzance section passes during the summer months, when it is concentrated into a few hours during the middle of the day at week-ends only. Thus a considerably higher relative capital expenditure on fixed equipment and locomotives is necessary than in the case of the Southern Railway, where the flow is more even throughout the year.

Turning to Table 1, the cost of the overhead line equipment at **£1,556,100** is appreciably greater than on comparable mileages elsewhere, as, owing to the unusually high proportion of curved to straight track, shorter spans than normal would be required between the structures carrying the overhead wires on **61** per cent. of the route. Considerable alterations to ways and works would be necessitated by the use of overhead conductors, and the railway telegraph, telephone, and signalling circuits would require modification to avoid interference to proper operation due to the use of the track rails for the return circuit.

The weight of the through passenger trains on this line ranges from **320** tons to **570** tons, and the consulting engineers consider that, taking into account the desirability of working the express and ordinary goods trains with a common stock of locomotives, it would be more economical to provide a small number of locomotives suitable for the heaviest passenger and express goods trains, and work the bulk of the traffic of all kinds on the main line by lighter and less powerful general-purpose locomotives. They therefore estimate for the provision of eight **140**-ton locomotives, each with six motors and an aggregate capacity of **2,550** h.p. on the one-hour rating, with a corresponding tractive effort of **37,500** lb. at about **25** m.p.h. for the heaviest services of both types, **40** loco-



Map of the lines between Taunton and Penzance which were proposed for electrification



TAUNTON - PENZANCE

Gradient profiles of the Taunton-Penzance main-line of the Great Western Railway for which estimates were made for conversion to 3,000-volts d.c. electric traction

motives with six 350-h.p. motors, and 55 with four 350-h.p. motors for the lighter passenger trains, and 61 of a smaller and cheaper type for the operation of small local trains, banking slow freight trains and shunting operations. The introduction of electric working would, it is

Table I.—Estimate of Capital Expenditure on Electrification.

Item	Description	Amount, including overhead charges	
		£	£
1	Overhead line equipment of 450 miles of single-track running lines and 133 miles of sidings, including bonding of the rails, cable connections, supervisory and telephone lines		1,556,100
2	Alterations to ways and works :—		
	(a) Bridges, water columns and loading gauges	59,400	
	(b) Track alterations near Taunton and Newton Abbot ..	70,000	
	(c) Telegraph and telephone circuits	50,000	
	(d) Signal and telegraph poles ..	35,000	
	(e) Track circuits and A.T.C. ..	53,200	
	(f) Capstans, including supply arrangements	22,000	
			289,600
3	Alterations to running sheds and repair shops		105,000
4	Substations and switch cabins		475,600
5	Electric locomotives and multiple-unit train equipments		2,554,000
6	Spare parts for electric locomotives and train equipments, substations and overhead line equipment ..		153,500
			5,133,800
	Less :		
7	Credit value of released steam locomotives	726,000	
8	Credit value of coal wagons, coal stock, steam locomotive spare parts	46,700	
			772,700
	Net capital expenditure (excluding expenditure, if any, in connection with the supply of power) ..		4,361,100

Table II.—Comparative Estimates of Annual Working Costs, Steam and Electric

Item	Description	Steam	Electric
		£	£
1	Locomotive coal, including freight ..	157,480	—
2	Electric power, delivered to the substations	—	202,610
3	Oil fuel for train heating	—	7,043
4	Water	7,477	152
5	Lubricants, stores, clothing and miscellaneous	12,439	6,420
6	Footplate staff	206,140	109,297
7	Locomotive preparation, maintenance and repairs	155,251	80,500
8	Superintendence	9,459	7,940
9	Maintenance of engine sheds, &c. ..	3,879	2,140
10	National insurance	21,452	14,500
11	Maintenance and operation of overhead line equipment, and substations	—	41,100
12	Additional maintenance of railway telegraph, telephone and other installations	—	1,375
		573,577	473,077

Saving in annual working costs due to electrification .. £100,500

Table III.—Capital Charges on Electrification Expenditure

Item	Description		Amount
			£
1	Depreciation on overhead line equipment		25,500
2	Depreciation on substations and switch cabins ..		9,415
3	Depreciation of locomotives :—		
	Electric	£42,600	
	Steam	12,000	
			30,600
4	Additional depreciation on railway telegraph, telephone and other installations		2,271
	Total net depreciation		67,786
	Balance of saving in working costs available for interest on net capital expenditure		32,714
	Equal to		0·75 per cent

estimated, release 165 steam locomotives and a quantity of spare parts, 300 coal wagons, and save a portion of the company's stock of locomotive coal. The estimated value of these items has been deducted from the capital expenditure, leaving a net capital expenditure, excluding any expenditure which might be required in connection with the supply of power, of £4,361,100.

Insofar as the question of power is concerned, the engineers have made a careful estimate of the energy consumption and of the maximum demand, and have estimated the annual cost of high-tension current, delivered to the substations, including interest and other charges on the capital, but do not, for various reasons, make any definite recommendations as to whether it would be advantageous for the company to generate or purchase the power. The estimates of steam and electric working costs in Table II are self-explanatory except that, in the case of footplate wages, it has been assumed that the electric locomotives would carry one driver without an assistant. Allowance has been made for reduction in banking and assisting time and of the shorter time required for preparation of the engine, but no allowance has been made for any increased mileage which might arise from speeding up. So far as Table III is concerned, the amounts for depreciation are calculated on a sinking fund basis on an agreed life, it being assumed that the payments would accumulate with compound interest at 3 per cent. In each case allowance has been made for the residual value of the asset. Deducting the net total of £67,786 per annum for depreciation from the saving in working costs of £100,500 there is a balance of £32,714 available for interest, this representing 0·75 per cent. of the net capital expenditure, a sum which is wholly insufficient to justify the company proceeding with the scheme.

NOTES AND NEWS

Norwegian Locomotive Order.—Eight express electric locomotives with the 1-Do-1 wheel arrangement, a top speed of 68 m.p.h., and a one-hour output in the neighbourhood of 3,000 h.p. are being built for the Norwegian State Railways by the Norsk Elektrisk Brown Boveri. They are to be equipped with high-voltage control apparatus.

German Electrification.—With the inauguration of the summer timetables on May 15, the Nuremberg-Saalfeld section of the Reichsbahn is to be turned over to electric traction. It forms the first section of the Nuremberg-Halle main line, now in process of conversion to the standard 15 kV 16⅔ cycles single-phase system.

Moscow Metro Proposals.—New schemes for the construction of seven new diametral lines and one circular line for the Moscow Metro, in addition to the two routes now under construction (see issue of this Supplement for March 31 last), have been drawn up. Construction of about 135 route miles of line is envisaged in the new proposals.

Norwegian Electrification Plans.—The Norwegian Storting recently discussed proposals for electrifying the Bergen-Voss line at an estimated cost of kr. 11,622,000, and the Nordagutu-Christiansand section of the Soerland railway at an estimated cost of kr. 16,035,000. Estimates have also been prepared for the conversion of the Lillestroem-Hamar line, the Kongsvinger railway and the Vestfold railway.

New Italian Electric Railway.—The new railway from Biella to Novara, 54 km., was recently opened by Il Duce. It is operated on the 3,000 volts d.c. system. There are several major constructional works on the line, such as the viaducts and bridges over the Rivers Sesia, Ostola, and Cerva, and one tunnel near Biella. This line is located in the centre of the Italian wool industry in Piedmont, and lies between Turin and Milan.

Swedish Progress.—As a result of the opening to electric traction of the Ange-Långsele, Bräcke-Oestersund and Goteborg-Uddevalla lines, as recorded in our issue of April 28, the Swedish State Railways now has about 2,250 route miles of line electrified, equivalent to over 46 per cent. of the whole system. More than 80 per cent. of the traffic is now hauled electrically, and the current consumption last year amounted to 545,000,000 kWh. An order for two express locomotives to a new design has been placed with Asea; the one-hour output of these new units will be approximately 3,500 h.p. and the top speed 135 km.p.h. (84 m.p.h.). It is expected that they will be able to haul 600-ton trains over the 283 miles between Stockholm and Gothenburg in a running time of 290 min., compared with the present shortest running time of 346 min.

Norwegian Electrification Progress.—On May 15 the doubling of the 12-km. (7½-mile) Kolbotn-Ski section of the Oslo-Kornsjø line (Østfold Railway) was completed, and the second track brought into use for the summer traffic. This will greatly facilitate the working of the increasing electric suburban services using the section, which is being electrified as part of the Oslo-Kornsjø electrification scheme, programmed for completion by July 1 next. The whole, Oslo-Ski line is some 25 km. (15½ miles) in length, and will be worked with the usual type of electric motor-coach described in the *Electric Railway Traction Supplement* of April 3, 1936, page 686.

Italian Electrification Figures.—An aggregate of 3,150 route miles of line of the Italian State Railways is now electrified on the 3,000 volts d.c., low-tension d.c., or 3,700 volts three-phase systems. During the fiscal year 1937–38, that is, before the Milan-Ancona and Rome-Leghorn lines were turned over to electric traction, the current consumption amounted to 873,000,000 kWh, from a figure of 457,000,000 kWh in the year 1934–35. Of this total consumption for 1937–38 approximately 450,000,000 kWh were generated in hydro-electric plants belonging to the State Railways, but new plants under construction or under consideration are expected to raise the railway-generated energy up to 700,000,000 kWh in 1941, to 1,100,000,000 kWh in 1943, and to 1,500,000,000 kWh in 1945, when the electrified route length according to present proposals will have reached 4,850 miles. Signor H. E. Benni, Minister of Communications, said recently that it had been decided to replace the three-phase electric traction between Viareggio and Genoa by 3,000-volts d.c., and thus give a through run on one system between Rome and Genoa. The three-phase section between Leghorn and Viareggio was replaced by high-tension d.c. last year, as recorded in the issue of this Supplement for December 9, 1938. A trial run is to be made with one of the Breda three-car streamlined electric trains between Rome and Florence in an endeavour to cover the 196 miles between the two cities in 120 min., an average of about 97 m.p.h. It will be remembered that in December, 1937, a special trial was made with one of these trains between Rome and Naples, when an end-to-end speed of 93·7 m.p.h. was attained over the 134 miles.

Electric Railway Traction

Southern Electrification 1923–1939

THE electrification of the lines from Gravesend, Swanley and Otford to the Medway towns marks the completion of the great conversion scheme instituted by the Southern Railway in **1935**, taking advantage of the Government's guarantees as to principal and interest on low-rate loans intended to facilitate the construction of works of public utility. The plans put forward four years ago comprised the conversion of the Guildford and Mid-Sussex routes to Portsmouth, the Aldershot and Reading groups of lines, and the extensions on the Eastern Section to the Medway estuary, aggregating upwards of **250** route miles.

Although Southern electrification may be traced by historians back to the first L.B.S.C.R. single-phase proposals, or even earlier if sub-surface lines are included, the nucleus of the present network was consolidated less than a dozen years ago, when the high-tension single-phase system disappeared and all suburban lines were standardised on the third-rail **660**-volt d.c. principle. Once a single system was in vogue, conversions further afield became more practicable propositions, and it is from this time that the main-line conversions date. The first was the Brighton and Worthing extension—opened in two stages, to Three Bridges in **1932**, and to Brighton and Worthing in **1933**. Prior to these dates, the Southern electrified suburban system comprised **300** route (**800** track) miles fed through **46** rotary converter substations with an aggregate installed capacity of about **200,000** kW. These lines were operated by nearly **1,850** electrically-operated coaches, running **20¾** million train-miles, consuming **326,000,000** kWh of energy, and carrying **218,000,000** passengers a year. Within six years the system has been more than doubled, and the steam lines electrified now comprise **702** route (**1,746** track) miles fed through **158** substations, and operated by **3,189** electrically-operated coaches running **41¼** million train miles a year.

The continuity of the Southern Railway chief officers most closely connected with electric traction has done not a little towards ensuring the rapid and efficient execution of the conversion works, and the utilisation of the new method of traction to give the public the kind of service it wants. Mr. G. S. Szlumper, the present General Manager, under whom the Portsmouth No. **2**, Reading and Medway schemes have come to fruition, was for many years assistant to Sir Herbert Walker, and it was under Sir Herbert's guidance that the Southern electrification took shape. Mr. Alfred Raworth, the company's Chief Electrical Engineer, has in that capacity, or in his former position of Electrical Engineer for New Works, prepared and carried out all the conversions since the amalgamation to the present time. All the engineering works connected with successive conversions from **1928** onwards have been carried out under the direction of Mr. George Ellson, the Chief Engineer, and the rolling stock has been the responsibility first of Mr. R. E. L. Maunsell, and since **1937** of his successor, Mr. O. V. Bulleid, the present Chief Mechanical Engineer. Finally, no better use could have been made of the facilities offered by electric traction than the splendid services—regular, quick, frequent and punctual—which have been a characteristic of train-working south of the Thames for a dozen years, and which were prepared first under the *ægis* of Mr. E. C. Cox, and later under Mr. E. J. Missenden, the present Traffic Manager.

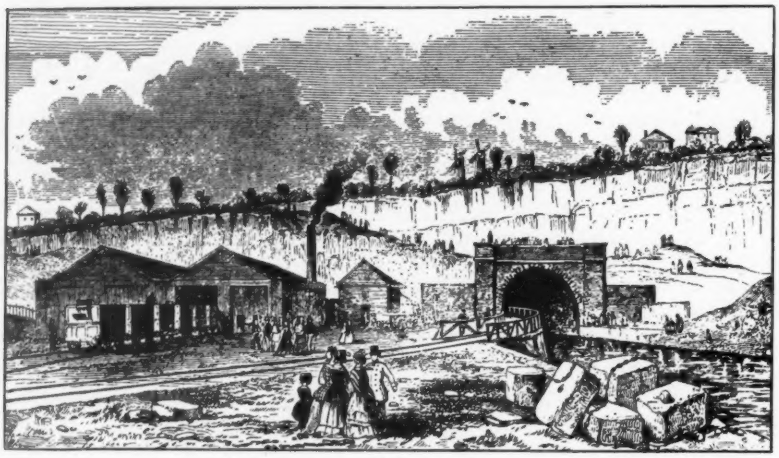
SOUTHERN RAILWAY ELECTRIFICATION MILESTONES.(8)

Routes	Route Mileage Electrified	Track Mileage Electrified	Approximate Conversion Cost £	Opening Date (Public)	No. of Sub-stations	Capacity of Substations kW(7)	No. of Vehicles
Prior to 1932 (Suburban)	300	800	7,000,000	1909–1930	46	201,500	1,813
Coulsdon and Purley to Brighton, West Worthing and Reigate	52	159	2,750,000	17-7-32(1) 1-1-33(2)	18	45,000	319
Bickley-St. Mary Cray-Sevenoaks; Orpington-Sevenoaks	23	50	500,000	1-5-34(3) 6-1-35(4)	6	15,000	41
Keymer Jct.-Ore; Brighton-Lewes; Copyhold Jct.-Horsted Keynes; Eastbourne, Seaford	60	118	1,750,000	7-7-35	17	42,500	188
Hampton Court Jct.-Portsmouth; Weybridge-Staines; Woking-Alton	96	252	3,000,000	3-1-37(5) 4-7-37(6)	26	67,500	312
Three Bridges-Ford-Havant; Dorking-Horsham; West Worthing-Arundel Jct.; Littlehampton and Bognor branches	75	162	2,750,000	2-7-38	20	50,000	292
Virginia Water-Reading; Ascot-Ash Vale; Aldershot-Guildford	43	88	1,000,000	1-1-39	10	25,000	72
Swanley-Gillingham; Otford Jct.-Maidstone E.; Gravesend-Rochester; Strood-Maidstone	53	117	1,750,000	2-7-39	15	37,500	152
Totals	702	1,746	20,500,000	—	158	484,000	3,189

(1) Coulsdon and Purley to Three Bridges and Reigate. (2) Three Bridges to Brighton and W. Worthing. (3) Bickley Jct. and Chislehurst Jct. to St. Mary Cray. (4) St. Mary Cray–Swanley–Sevenoaks and Orpington–Sevenoaks. (5) Hampton Court Jct.–Weybridge–Staines. (6) Weybridge–Guildford–Portsmouth Harbour and Woking–Alton. (7) All rectifier substations have one 2,500-kW rectifier except Newhaven and Fratton, which have two each. (8) Figures refer to steam lines converted.

THE MEDWAY GROUP OF LINES

By CHARLES E. LEE



***The Strood entrance to the canal tunnel after a single line of rails had been laid through it in* 1845**

THE sections of the Southern Railway that are being opened for electric traction on July 2 may be termed the Medway group of lines, for one of them (Strood to Maidstone) roughly parallels that river, and the others consist of the former competitive lines of the South Eastern Railway and the London, Chatham & Dover Railway which crossed the Thames—Medway watershed in linking the Metropolis with the important Medway towns of Chatham and Maidstone.

As a line of communication, by far the oldest is the Gravesend—Strood portion, for it was at the end of the eighteenth century that the Thames & Medway Canal was projected to facilitate the passage of vessels from Medway ports to London, saving at least **30** miles by enabling them to avoid sailing round the Isle of Grain. The work took **24** years to complete, largely by reason of a lengthy tunnel through the chalk hills between Higham and Strood, and the formal opening of the canal took place on October **14, 1824**. Twenty years later the canal company built a single-track railway, mainly along the towing path of the canal, which began at Milton near Gravesend, and terminated at Strood, opposite Rochester. The engineer for the work was the famous John Urpeth Rastrick.

The tunnel, 2¼ miles long, was in two sections, one of **69** chains and the other **1** mile **26½** chains, separated by a 4-chain opening. Being dead straight throughout its length, it was possible from one entrance to see the light at the other. The towing path through the tunnel was originally **5** ft. wide, and to accommodate the single-track standard-gauge railway the width was increased to about **10** ft. by a timber framework upon piles. The waterway of about **21½** ft. was thus reduced to **16½** ft. The company had hoped to open the railway early in September, **1844**, and in July of that year notified the Board of Trade that the line was ready for inspection. Maj.-General C. W. Pasley, the Inspector-General of Railways, examined the works with great care and reported unfavourably on the strength of the timber framework, although expressing complete satisfaction with Rastrick's general plan. Strengthening works were therefore undertaken, involving the company in the further cost of about **£6,000**, and eventually the railway was opened on February **10, 1845**. Originally the passenger fares were **1s.** first class and **8d.** second class, but on March **17** they were reduced to **9d.** and **6d.** respectively.

The Gravesend & Rochester Railway & Canal Company, as the undertaking had become, was bought by the South Eastern Railway Company for **£310,000**, under an Act of August **3, 1846**, which also authorised filling up as much of the canal as was necessary to form part of the North Kent Line (for which the S.E.R. had obtained powers) from New Cross to Gravesend. The tunnel was drained and the railway, widened to two tracks, opened on August **23, 1847**. Through railway communication between London and Strood was established on July **30, 1849**, when the North Kent Line to Gravesend was opened; the extension from Strood to Maidstone was brought into service on June **18, 1856**.

East of Chatham the country was still unprovided with railways on the route of the main road to Dover, but on August **4, 1853**, the East Kent Railway Company was incorporated as a local venture with powers for a line leaving the South Eastern at Strood and running through Chatham and Faversham to Canterbury. The Faversham—Chatham section was opened on January **25, 1858**, and connected across the Medway to Strood on March **13**. As the result of a series of quarrels and misunderstandings, the East Kent, on August **1, 1859**, changed its name to the London, Chatham & Dover Railway, having obtained powers in the previous year for independent access to London. This was effected by means of a new line from Rochester Bridge *via* Sole Street to Bickley, opened on December **3, 1860**.

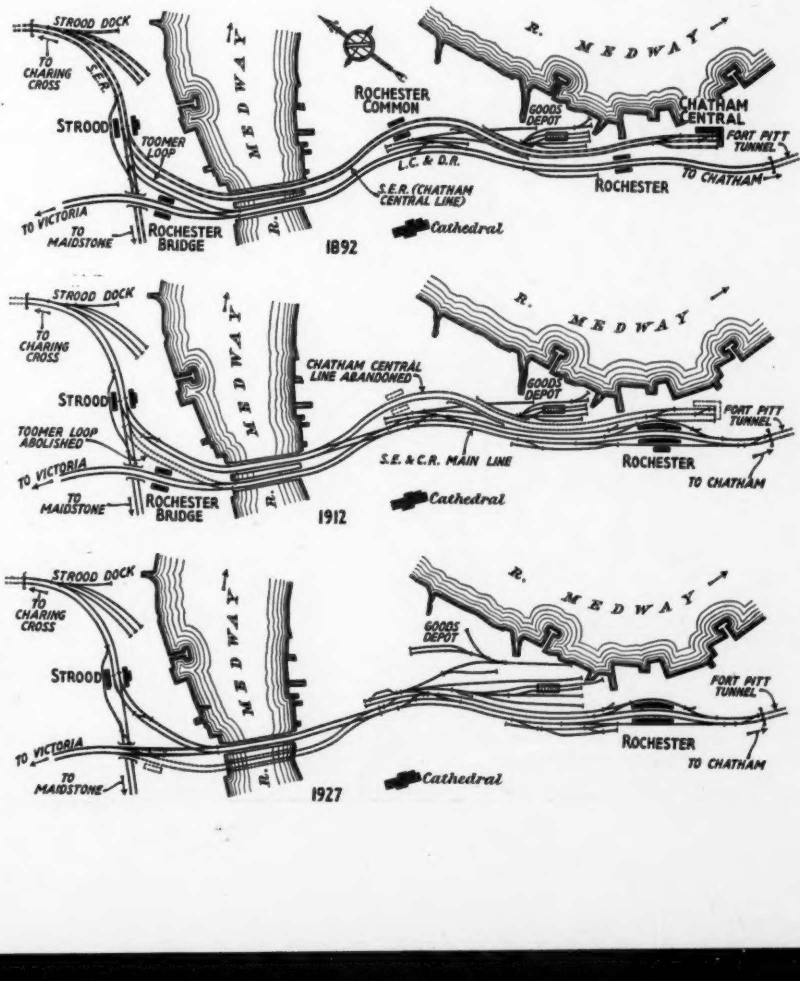
From that date the L.C. & D.R. began running to Victoria, using the tracks of the Mid-Kent (Bromley to St. Mary Cray) Railway, the West End of London & Crystal Palace Junction Railway, and the Victoria Station & Pimlico Railway. To serve Strood, a station was opened on the west bank of the Medway, which, after undergoing various changes of name, became known as Rochester Bridge, and remained in use until January **1, 1917**, when it was closed. As soon as the L.C. & D.R. had independent access to London, it had no desire to pass traffic to

the S.E.R., and accordingly abandoned passenger service over the loop to Strood, and also through booking from L.C. & D.R. stations to S.E.R. stations. A limited goods service was continued with two (at first) and subsequently one train daily in each direction, but both companies placed such restrictions on the traffic that it was of only limited value to Chatham and district.

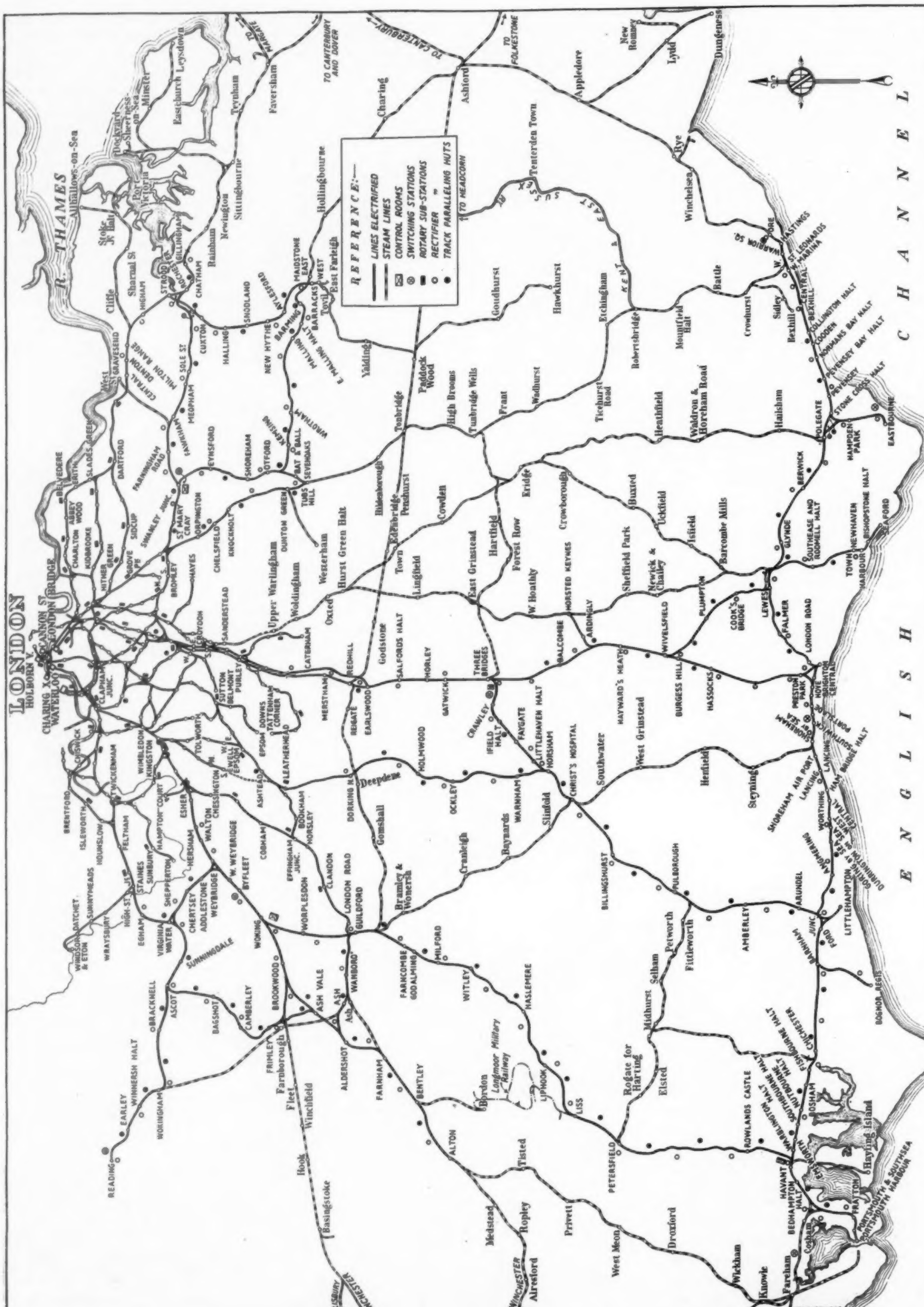
These were the conditions obtaining in 1876, when Mr. N. E. Toomer, then Mayor of Rochester, and others brought the matter before the Railway Commissioners under the Regulation of Railways Act, 1873. In the course of a comprehensive inquiry evidence was given that in May, 1873, the S.E.R. proposed to the L.C. & D.R. to run through carriages between Strood and Chatham off the North Kent trains, and in September, 1875, that all London—Strood trains should run to and from Chatham, but the L.C. & D.R. saw operating difficulties (such as in turning locomotives at Chatham) and refused. The Railway Commissioners gave judgment on January 6, 1877, ordering adequate exchange facilities at Strood to be provided at once by the two companies, and setting forth that the Act authorising the original East Kent Railway (1853) and the subsequent Western Extension Act (1858) for the line to Bickley contained not only "facility" clauses, but also required the respective railways to facilitate exchange traffic. A second order, slightly amending the first, was made on February 9, but some weeks afterwards representations were made that the order had not been complied with by either railway, and on March 14 the Railway Commissioners made a further order carrying penalties against the L.C. & D.R. of £60 a day, and against the S.E.R. of £15 a day, for non-compliance after April 1, 1877. Only then was a service provided over the loop, with through bookings *via* Strood. Thereafter the name Toomer was commonly applied both to this service and to the connecting loop.

After the L.C. & D.R. opened its own route to London, the S.E.R. supported a bus service between Chatham and Strood station, and, despite the "Toomer" train service, made no great effort to encourage traffic to the L.C. & D.R. The rivalry between the two railways in the Chatham district culminated in 1892, with the completion of a branch of the S.E.R. from Strood to Chatham Central. The section from Strood to Rochester Common station was opened on July 19, 1891, and thence to Chatham Central on March 1, 1892. This line necessitated a second bridge over the river, alongside the existing structure, and a long length of viaduct beyond. After the formation of the South Eastern & Chatham Railway Companies' Managing Committee, in 1899, the branch became redundant, and in 1911 the whole line east of the river was dismantled. The last train on the Chatham Central branch ran on Saturday night, September 30, 1911. These alterations included the abandonment of the L.C. & D.R. Toomer loop, which was replaced by a new junction on the opposite side of the Medway.

The North Kent line bridge over the Medway was thrown out of use on June 29, 1919, by a fire which destroyed the timber decking. The Toomer loop and junction with the Chatham main line were rapidly reconditioned and reopened as an emergency measure on Friday, August 1, 1919, together with Rochester Bridge Junction signal box, but were again placed out of use on Sunday, January 8, 1922, when the North Kent line bridge was again reopened. Finally, in 1927, the alignment of the curves at the foot of the Sole Street bank on the main line was improved. A new bridge was constructed over the Maidstone extension of the North Kent line, and all traffic diverted over the newer Medway viaduct. The original L.C. & D.R. viaduct and Rochester Bridge station lie derelict, as the railway now passes outside the platforms.



Maps showing the layout of the railways in the Strood-Rochester area at various periods from 1892 onwards. All the running lines shown in the 1927 plan have now been electrified, but slight track alterations have been carried out at Strood, as shown in the track diagram of that station reproduced elsewhere in this issue



Map of the existing Southern Railway electrified system, extending over 702 route miles

Traffic Operation

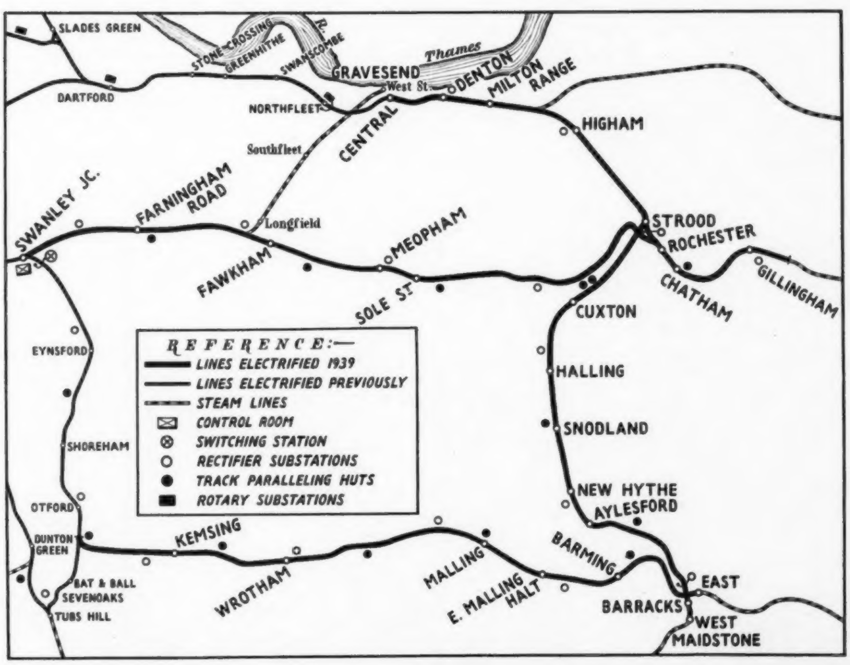
BECAUSE of the already fairly dense steam traffic over the lines in the Strood, Chatham, and Maidstone area, the increased mileage of the electric services is not of such magnitude as one has been accustomed to count as normal with Southern Railway electrification extensions, although actually no complaint could be lodged against the increase of almost 43 per cent.—1,866,540 electric-train miles replacing 1,308,132 steam-train miles. Despite an acceleration of anything from 9 to 23 per cent. between London and the Chatham—Maidstone area, it is in the standardised times and the great increase in the number of through trains that the benefits of electrification are fully realised. For example, between Victoria and Maidstone East the service of 22 down and 21 up trains daily is now 100 per cent. through, whereas previously only 11 down and 12 up trains out of 21 and 20 respectively were through, and they ran at odd times compared with the standardised departures characteristic of the timetables being introduced on July 2.

The basic train unit is a two-car set composed of one non-vestibuled corridor coach and one compartment coach, both 9 ft. wide. Trains of eight cars will be operated at hours of peak traffic, and it is not unlikely that trains up to 12 cars will be run to the Chatham area at holiday times or on special days. A total of 76 two-car sets has been built for the new services, and these 152 vehicles displace 140 ordinary coaches and 15 engines. About 50 sets of enginemen have been displaced, but the more intense electric train service requires 20 additional guards. Gradients of 1 in 100 are met with on the Chatham—Sole Street section; otherwise there are no banks of a steepness or length to cause trouble either to steam or to electric trains. But the extremely congested layout in the neighbourhood of Strood (including sharp curves, tunnels, numerous junctions, and, in fact, most things a railway could well do without) will not be such a source of delay and inconvenience with the quicker acceleration, reduced terminal movements, and smokeless operation of electric traction.

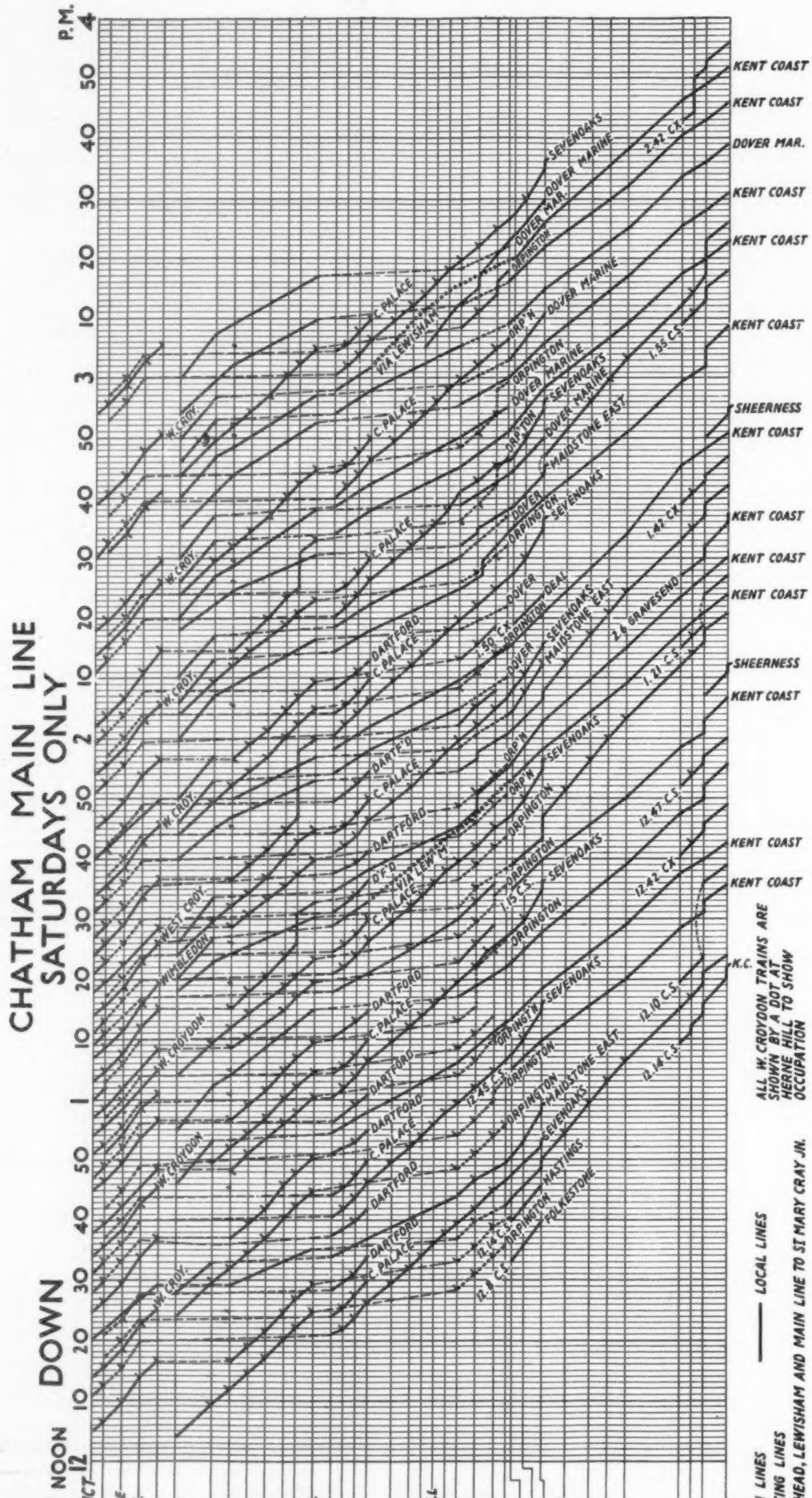
Services from Charing Cross and Cannon Street

Normal services on weekdays comprise trains running between Charing Cross or Cannon Street and Gillingham (with a portion for Maidstone West) *via* Woolwich and Gravesend, and a combined service between Victoria on one hand and Gillingham and Maidstone East on the other, the train being split or made up in the loop platforms at Swanley. The junction of the Gillingham and Maidstone West portions is at Strood. The basis of the service from the central and east London termini to the Medway is one train an hour leaving Charing Cross at 42 min. past the hour from 7.42 a.m. to 11.42 p.m., and calling at Waterloo, London Bridge, Woolwich Arsenal, Dartford, Gravesend Central, Strood, Rochester, Chatham, and Gillingham. The Maidstone West portion calls at all intermediate stations between Strood and its terminus. In the reverse direction the trains leave Gillingham at 10 min. past the hour from 7.10 a.m. to 11.10 p.m. and Maidstone West at 55 min. past the hour from 6.55 a.m. to 10.55 p.m.; they combine at Strood and thence to London make the same stops as the down trains.

By extending to Gillingham one of the existing Charing Cross or Cannon Street stopping electric trains to Gravesend, a second service each hour is provided. This train stops at all stations between the London terminus and Gillingham, and nominally leaves Cannon Street at 55 min. past the hour. Connecting with it at Strood is a shuttle service of electric trains to Maidstone West. Although the two trains an hour leave London within 13 min. of each other, the arrival times at Maidstone West are at



Map of north-east Kent area showing the Gravesend–Rochester, Swanley-Gillingham, Strood-Maidstone West, and Otford junction—Maidstone East lines converted to 660 volts d.c. electric traction. The regular public service with electric trains begins on July 2



Graphic timetable of the down service in the middle of the day on summer Saturdays over the London–Chatham lines covered by the recent electrification extension

HEAD CODES, SERVICES FROM CHARING CROSS AND CANNON STREET

Service	Route	Route Indication: Main-Line Stock	Route Indication: Sub-urban Stock
Charing Cross to Gillingham	Chislehurst	08	—
Charing Cross to Gillingham	Parks Bridge and Loop Line	42	$\overline{L}$
Cannon Street to Gillingham	Parks Bridge and Loop Line	43	$\underline{L}$
Charing Cross to Maidstone West	Parks Bridge and Loop Line	46	$\overline{L}$§
Cannon Street to Maidstone West	Parks Bridge and Loop Line	47	$\underline{L}$§
Charing Cross to Gillingham	Lewisham and Loop Line	52	$\ddot{L}$

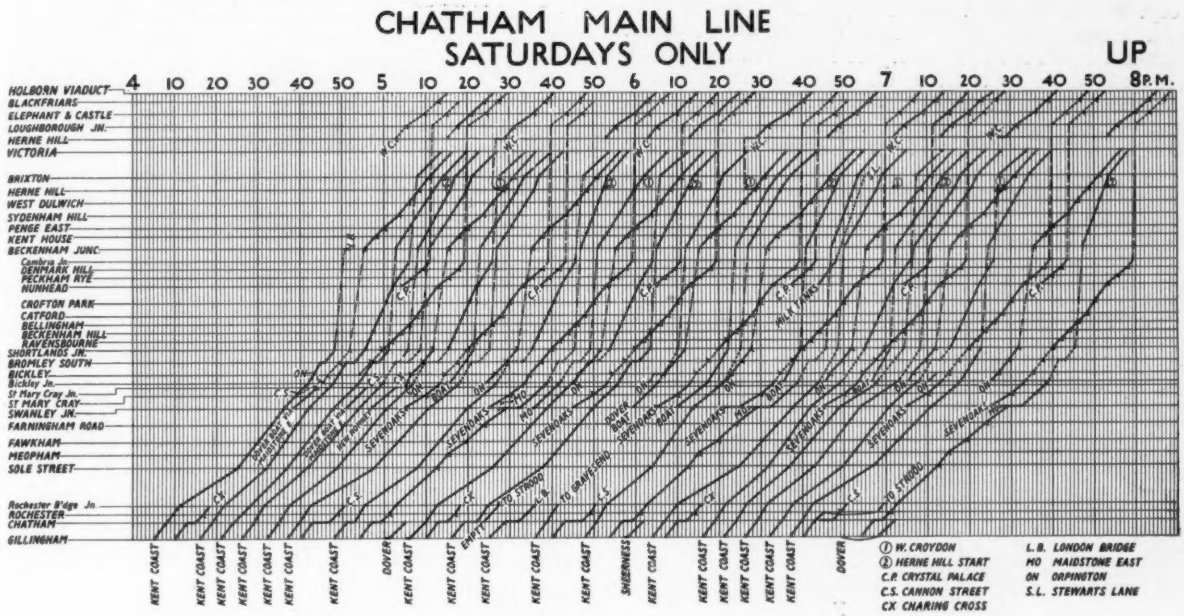
§ Code to be changed at Gravesend Central to $\dot{S}$, $\dot{L}$, $\dot{P}$, or $\dot{V}$, according to the route.

HEAD CODES, SERVICES FROM VICTORIA AND HOLBORN

Service	Route	Route Indication
*Victoria and Gillingham	Herne Hill ..	90
*Victoria and Gillingham	Catford Loop	92
*Victoria to Maidstone East	Herne Hill ..	94
*Victoria to Maidstone East	Catford Loop	96
*Holborn to Gillingham	Herne Hill ..	91
*Holborn to Gillingham	Catford Loop	93
*Holborn to Maidstone East	Herne Hill ..	95
*Holborn to Maidstone East	Catford Loop	97
London Bridge to Gillingham	Chislehurst ..	07
Gillingham to Charing Cross	Chislehurst ..	08

* Empty trains to carry relevant route indicator with a bar placed thereover, thus: $\overline{96}$

Other empty electric trains to carry □



Graphic timetable of train services on the recently-electrified London—Chatham line, showing the up service on Saturday evenings in the summer

regular half-hourly intervals. Similar arrangements are in force in the up direction, with trains leaving Maidstone West at **27** min. past the hour and arriving at Cannon Street, after the change at Strood, at **5** min. past the hour, giving a journey time of **98** min. for the **41½** miles, compared with the **83** min. of the semi-fast service over the **42½** miles to Charing Cross.

During the business periods on weekdays and Saturdays the service is augmented by extra trains to and from London, and by an extra shuttle service between Strood and Maidstone West, giving in the aggregate an average of four trains an hour between Gravesend, Gillingham, Strood, and Maidstone. In the morning and evening rush hours some of the shuttle trains on the Strood—Maidstone West section are made up in eight-car formation to accommodate the heavy workman's traffic between the Strood—Chatham and Maidstone areas and the cement works and paper mills near Cuxton, Snodland, and New Hythe, at all of which additional passenger and freight facilities have been provided.

Victoria-Medway Trains

At **18** min. past each hour from **7.18** a.m. to **10.18** p.m. a semi-fast train leaves Victoria to serve Gillingham and Maidstone East. It stops first at Bromley South and then at Swanley, where it divides, the front portion running to Maidstone East and stopping at all stations *en route* except Eynsford and Shoreham (which are served by the existing Sevenoaks electric trains), and the second portion going to Gillingham *via* Sole Street and stopping at all stations on the way. There are return services of a similar character leaving Maidstone East at **49** min. past each hour from **7.49** a.m. to **10.49** p.m. and Gillingham at **54** min. past each hour, the two train sets combining at Swanley and reaching Victoria at **59** min. past the next hour. The standard times for the **41** miles between Victoria and Maidstone East are **65** min. down and **70** min. up; the corresponding schedules for the Gillingham portions are **63** min. down and **65** min. up for the **36** miles. At business periods certain additional trains on the Maidstone East and Gillingham lines start from or terminate at Holborn Viaduct, and extra trains are also run to or from Victoria station.

Frequency and Acceleration

The electric train weekday timetables show **43** down and **42** up trains a day between London and Maidstone West with average timings of **93** min. and **91** min. respectively, compared with **24** down and **22** up steam trains with average schedules of **106** min. and **108** min. Of these, **20** are through trains and **23** involve a change at Strood in the down direction, and the figures in the reverse direction are much the same. In steam days there was only one down through train and none in the up direction. To Chatham from Charing Cross and Cannon Street there are **49** down and **46** up trains a day during the week, running to average schedules of **69** min. and **68** min. respectively, and compared with **40** and **38** steam trains running at irregular intervals and averaging **77** min. and **76** min. in the up and down directions respectively. The service between these two London termini and Gravesend Central now comprises **82** down and **80** up services on weekdays, running *via* the four alternative routes to Dartford.

From Victoria and Holborn Viaduct there are **22** down services a day on weekdays to Maidstone East and **33** to Chatham, the average times being **67** min. and **60** min. respectively; in the up direction there are **21** trains from Maidstone East with an average timing of **70** min. and **27** trains from Chatham running to an average end-to-end timing of **61** min. These compare with **21** down and **20** up steam trains on the Maidstone East line with times of **84** min. and **87** min. respectively, and **28** down and **22** up trains on the Gillingham *via* Sole Street line, with average schedules of **70** min. and **74** min. Swanley station now has **79** down and **77** up passenger trains a day during the week, these numbers including the existing Holborn Viaduct—Otford—Sevenoaks electric trains.

There are only minor changes in the number of trains run on Saturdays compared with the weekday service,

except on the Chatham route from Victoria, where additional steam trains call during the summer months. Week-end traffic is not so heavy to the towns on the new electrified extension as it is on certain other Southern routes, such as those to Brighton, Eastbourne and Hastings; therefore the Sunday service is appreciably less than that given on weekdays. The London—Gravesend—Maidstone West line has 32 down and 34 up trains on Sundays against 43 and 42 on weekdays, and the same route to Gillingham is served by 37 down and 34 up workings compared with 49 and 46 on weekdays. Similarly, Maidstone East has 16 down and 17 up services on Sundays, and all run to Victoria, whereas on weekdays there are 22 down and 21 up trains, some of which use Holborn Viaduct at the London end.

Another feature of the new timetables, shared with those on other Southern electrified sections, is the number of late trains. For example, with steam traction the last down train to Maidstone West left Charing Cross at 9.47 p.m. and involved a change at Strood, whereas now there are two through and two changing services after that time, culminating in the 11.42 p.m. through train from Charing Cross. The last train from Victoria to Chatham leaves at 11.40 p.m., 56 min. later than the last train in steam days.

THROUGH TRAINS, WEEKDAY SERVICES

Between	Steam		Electric		Percentage Increase in Through Services
	No. of Services	No. of Through Services	No. of Services	No. of Through Services	
Charing Cross and Cannon Street and Maidstone W.	24	1	43	20	1,900
Charing Cross and Cannon Street and Chatham	40	16	49	49	206
Victoria and Holborn Viaduct and Maidstone East	21	11	22	22	100
Victoria and Holborn Viaduct and Chatham	28	19	33	33	74

ACCELERATION FROM LONDON, WEEKDAY SERVICES

From London to	Steam trains, min.	Electric trains,* min.	Gain, per cent.
Chatham *via* Gravesend ..	76	62	18
Maidstone West *via* Gravesend	106	81	24
Chatham *via* Sole Street ..	70	60	14
Maidstone East *via* Swanley ..	84	67	20

* Semi-fast services

Traffic Density

Particularly over the Gillingham—Rochester Bridge junction and Swanley—Chislehurst loop sections, some difficulty was experienced in getting the increased electric service to regular times, for in the summer there is a heavy traffic to and from the Kent coast resorts *via* Swanley, Sole Street, and Chatham, and, to a lesser extent, over the Maidstone East—Otford—Swanley route, and naturally it was not desired to alter the timings of these trains to any great extent. Moreover, between Swanley and London and between Gravesend and London, the new trains have had to be dovetailed with existing electric and steam services using the same tracks or crossing their paths at a dozen junctions. Again, the freight traffic during the day on the Gravesend—Chatham and Medway valley lines is by no means negligible, and on other sections, such as that between Gravesend and Hoo junction, a service of local steam passenger trains to and from the Allhallows branch also uses the same tracks as the electrics. The density of the traffic in the London area and in the Rochester-Gillingham district can be judged from the accompanying graphic timetables.

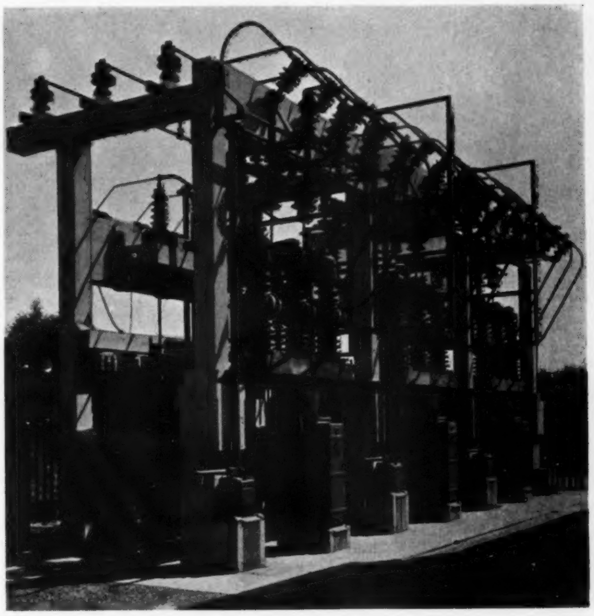
An eight-car train of the new 9 ft. compartment and corridor stock, made up of four two-car units

Power Supply and Distribution

THE mileage involved in the new electrification extension is 53 route and 117 track miles, bringing the Southern Railway's electrified totals up to 702 route and 1,746 track miles respectively. The lines just electrified, viz., Gravesend—Maidstone, Swanley—Gillingham, and Maidstone—Otford junction, are fed through 15 rectifier substations.

The Central Electricity Board's transforming substation at Northfleet, which is one of the supply points for the Sevenoaks area electrified lines, is the main source of supply for the new extension. Originally, one 33 kV feeder cable was laid from Northfleet to a high-tension switching station at Swanley, and this cable has now been used to feed the two additional substations lying along its route, namely, at Tweed Hill and Fawkham. In addition, a new 33 kV feeder circuit has been added at Northfleet, which follows the North Kent railway route to Strood and Maidstone; two ring main loops are formed by extending the feeder cable from Greenhill substation to Maidstone and from Fawkham to Strood, as shown in the accompanying power distribution diagram.

Previously Swanley was used only for the feed-off to Eynsford and Greenhill substations, although the h.t. feeder from Northfleet went through it to Kevingtown and Chelsfield. With the opening of the Gillingham extension its function has become more important, as it makes possible a duplication of supply from Tunbridge Wells, by feeding through Chelsfield and Kevingtown if there should be any defect at Northfleet. Moreover, any fault in the distribution system in the Higham, Strood or Meopham areas can be countered by feeding the supply *via* Eynsford, Borough Green, and Maidstone. The ring mains are not normally paralleled, but instead the feeders are operated as on a radial system. A new Southern Railway switching station has been built at Swanley consequent upon the re-siting of Swanley passenger station, and now occupies the site of the up branch platform of the old Swanley Junction station. The change-over was carried out without any interruption to normal services.



High-tension outdoor switchgear mounted on new design of reinforced concrete framework

The 33 kV power cables comprise three single-core paper-insulated lead-covered cables compounded and served. The leading-in lengths at the substations are protected by a single layer of non-magnetic armoured wire. These cables are run in the usual manner in wooden troughs supported on concrete posts, except where local conditions necessitate their being laid in concrete ducts, as at level crossings and stations.

All the substations on this extension are of the same size, but represent a radical change in design from that hitherto adopted. The technical arrangement remains the same, but the substation has been re-designed to accommodate a new type of circuit-breaker which enables a considerable economy of space to be obtained, and the rectifiers have been provided with new equipment. A simplification has been made in the design and construction of the substation building and framework for the outdoor switchgear.

Previously, in common with general practice, use has

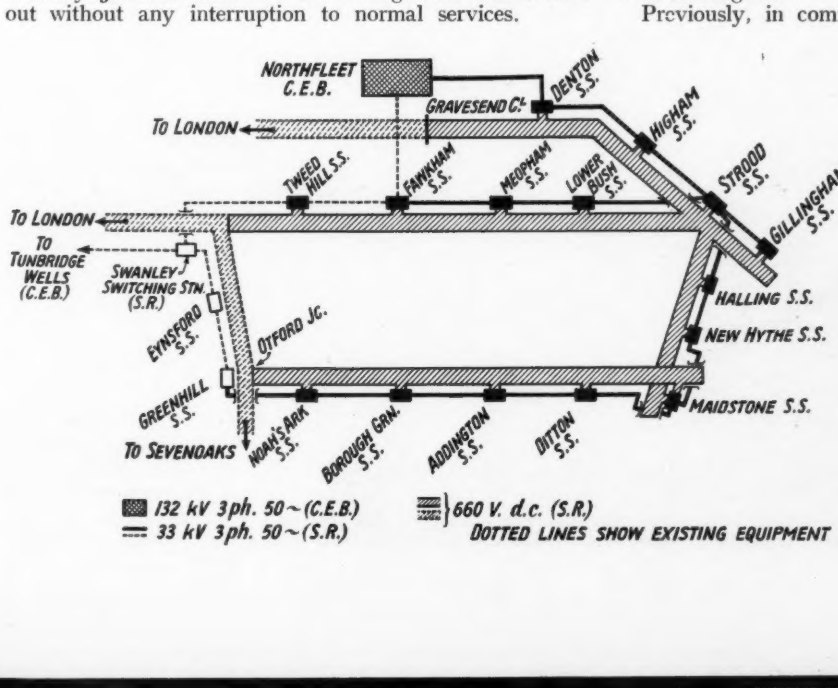
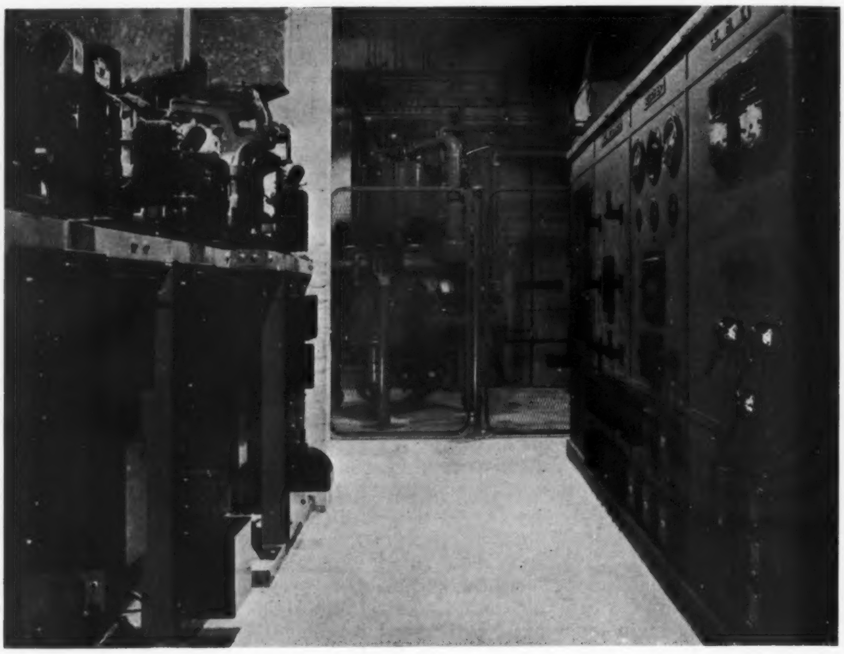


Diagram of the power supply and distribution system of the Gillingham and Maidstone lines. At Swanley the new system forms an extension of the St. Mary Cray—Sevenoaks line electrified in 1935, and at Gravesend connects with the suburban electrified lines of the Eastern Section

Interior of Meopham substation showing (left) the d.c. breakers, (centre) the grid-controlled mercury-arc rectifier, and (right) the substation control panel. Showing above the far end of the control panel is the recooler



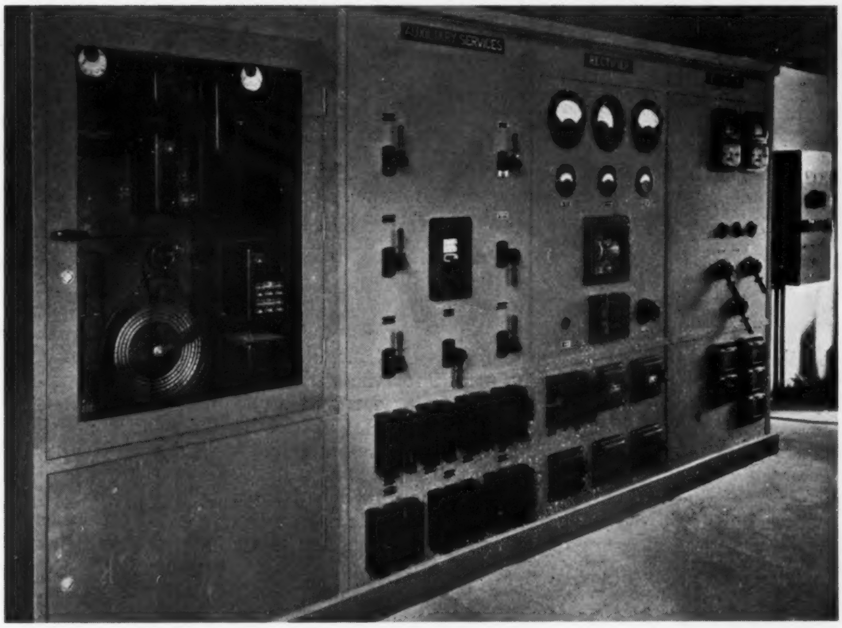
been made of the conventional type of oil circuit-breaker, in which oil is used not only to quench the arc but also to act as a dielectric between phases and earth. It is now known that only a very small fraction of the total oil quantity is needed to quench the arc, leaving the greater proportion to act solely as a dielectric. The new type of oil circuit-breaker omits this large proportion of oil and, instead, uses solid non-inflammable insulating material and air as a dielectric. It is called an " oil minimum contraction circuit-breaker," and the only oil used is that needed for quenching the arc and for establishing the required dielectric strength between the contacts for an instant during breaking, *i.e.*, until the isolator blades have opened. By this means the quantity of oil required is reduced to a small proportion of that needed in the conventional oil circuit breaker, and the fire risk associated with large quantities of oil exposed to open arcing is eliminated.

These circuit-breakers, which are of the single-pole single-break type with combined isolating switch, are formed into three-phase units and mounted on steel channels suspended between the vertical joists of a reinforced concrete structure. This structure supports the whole of the **33** kV switchgear required at each substation, and is arranged in bays for the individual circuits which are separated by screens and can be isolated at will. The current transformers necessary for protective purposes are separately mounted, and being of the ring type are slipped over the incoming **33** kV cables and interconnector to the main transformer. Auxiliary supplies are provided by two **45** kVA three-phase transformers, which are connected through h.t. switch fuses to each of the incoming feeders.

The layout of the indoor equipment has also been modified as compared with the substations of previous extensions. The annexe housing the recooling equipment has been abandoned, and a recooler of a new type is now situated behind the rectifier itself. Thus a completely rectangular building results, which in a four circuit-breaker type building, measures **40** ft. by **18** ft. Further, the substations are of unfaced brick, compared with the overlaid brick used for the majority of previous substation buildings, and which has proved troublesome to keep clean.

As before, the converting plant comprises an oil-cooled step-down transformer mounted outside the end wall of

A view of the exterior of Meopham substation, showing the neat design and proportions of the rectangular building now used for the standard 2,500-kW rectifier substations



Substation control panel showing, erected within one framework, the apparatus for the high-tension switchgear, the rectifier equipment, the substation auxiliaries, and the supervisory system of remote control

the substation building, and directly connected to a mercury arc rectifier immediately adjacent inside the building. The rectifier is of the steel tank type of the Southern Railway's standard output, viz., 2,500 kW at 660 volts d.c. on the continuous rating. It is provided with the usual closed circuit water cooling thermostatically controlled, but the anodes are air-cooled instead of being water-cooled as hitherto. Another new feature incorporated in the units is arc suppression equipment, which consists of controlled grids intended to suppress the arc under a backfire condition, and to ensure that the supply is automatically re-established. The new layout and equipment is applied to 13 of the 15 new substations, Fawkham and Tweed Hill, which were inserted in the existing feeder from Northfleet to Swanley, having been made duplicates of the previous Sevenoaks area substations.

The automatic equipment and other apparatus for the control of the substation is housed in a common switchboard comprising four panels, viz., e.h.t., rectifiers, auxiliaries, and supervisory. The high-speed d.c. circuit-breakers are mounted on a concrete shelf in the standard manner, each with its respective control panel mounted on the supporting framework of the shelf. The d.c. positive busbar arrangement is the same as before with four 4 in. by ¼ in. copper connections leading from the rectifier cathode in a trench to a main 4,000 amp. high-speed circuit-breaker which feeds the busbar to which all the feeder 2,500 amp. circuit-breakers are connected. These circuit-breakers are usually closed by current obtained from the 660-volt busbar, but certain units are provided with a device to enable them to close by current from the conductor rail when the respective rectifier is not in operation. These feeder breakers are connected to the conductor rail by 1·0 sq. in. cables; the negative feeders consist of 0·75 sq. in. cables connected to the track rails, and return the current to the negative busbar, which is located near the main transformer and to the neutral point of which the busbar is connected through the absorption coils.

Following standard practice, track-paralleling huts are placed midway between the substations; they contain automatic high-speed circuit-breakers which parallel the tracks in order to take advantage of all the cross-sectional area of the conductor rails and thus ensure the minimum possible voltage drop. The conductor rails themselves are of the Southern Railway's standard flat-bottomed section weighing 100 lb. a yd. They are normally in 60 ft. lengths, and are bonded together by four copper bonds having a total c.s.a. of 1·66 sq. in.

All the substations are unattended and are operated by the same supervisory system of control as on previous electrification extensions. The existing control room at Swanley has been increased to more than twice its original size and is now of similar dimensions to the control room at Woking. To the existing 14 panels another 40 have been added, and on these are represented diagrams of the whole of the main power circuits for the supply of energy to the conductor rails, made up of mimic busbars and switch units covering each substation and track-paralleling hut. The functions carried out by this remote control system are the operating and indicating of the h.t. oil switches and d.c. high-speed circuit-breakers; the remote metering of the d.c. amperage and voltage; fault signalling when the position of any switch does not agree with the indication of the switch at the control room; and telephonic communication between all substations and control rooms.

The medium by which these operations are carried out is a selector system of remote control, which requires for its operation a transmitter at the control room and a receiver at the substation; these two pieces of apparatus are housed in cubicles with their attendant relays and other automatic devices. Each selector requires four conductors and one common return for its operation, and as two substations are operated on each selector the total number of cores is consequently determined and grouped for convenience into a number of substations in series. The standard sizes used for this and all previous extensions is a 33- or 17-core cable (depending upon the location in respect to the control room) and this is run concurrently with the 33 kV cables, supported on the same concrete posts but housed in a separate trough together with a four-core pilot cable. This pilot cable is used in conjunction with the e.h.t. balanced feeder protection equipment, the function of which is to isolate a feeder section between substations in the event of a phase or earth fault.

Civil Engineering

THE incidentals of a railway electrification scheme are well shown by the works undertaken by the Chief Engineer's staff in connection with the Gillingham extension, for with the exception of the new station at Swanley and the rebuilding of Strood station, they are mainly of a minor character and yet some of them are well away from the scene of electrification.

New Station at Swanley

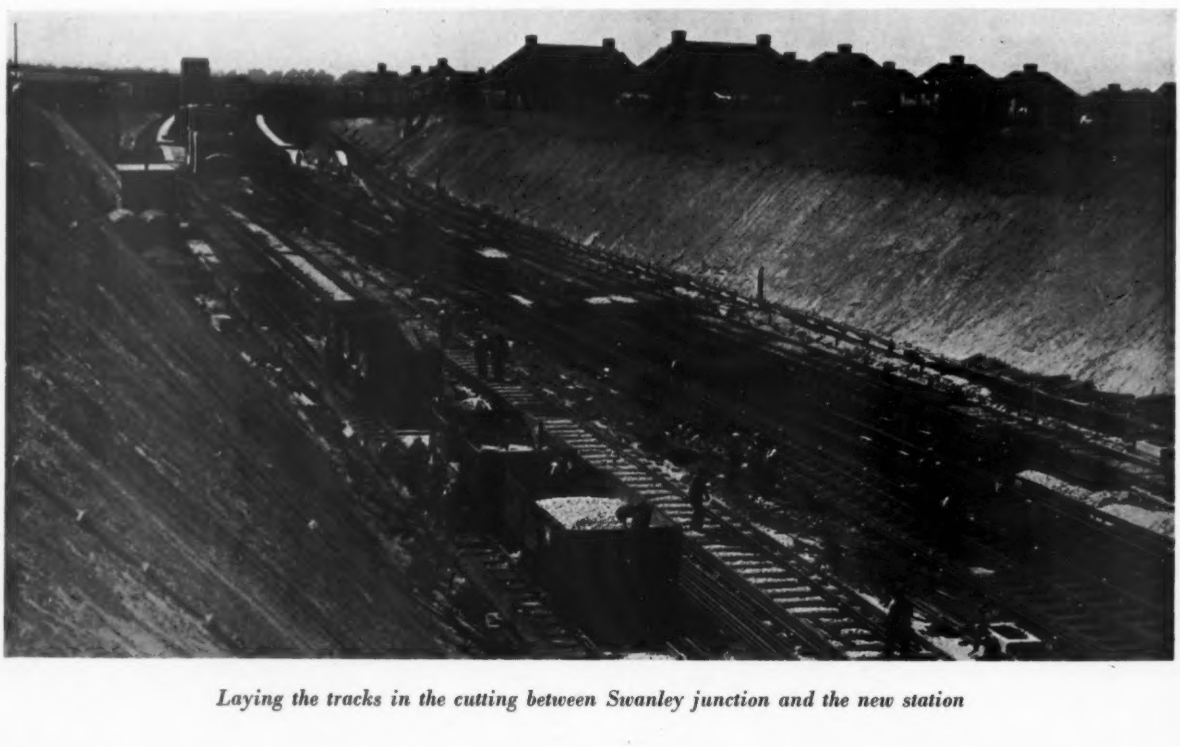
Although the old Swanley Junction station was suitable for the traffic existing before the new electrification, it was inadequate and awkwardly placed for the make-up and break-up of electric trains for the new services, and the growing traffic of the district was beginning to need more accommodation. The Junction station has therefore been demolished, and a new station with two 820 ft. island platforms, suitable for taking 12-car trains, has been built just west of the junction, and is known simply as Swanley. The tracks are so arranged that parallel movements can take place in the through and bay roads, as explained in the section on traffic operation. The cutting at this point has had to be widened considerably to house the new station, and the h.t. switching station by which current is taken from the grid, has been moved eastwards to the site of the old up platform of the Otford branch, and is now close by the control room, which has itself been increased in size by about 100 per cent. for the inclusion of the panels and selector apparatus for the 15 new sub-stations and 12 track-paralleling huts.

Temporary approaches to the up and down platforms are completed but the final approaches and other details cannot be constructed until a decision is made as to the exact location of the new arterial road which is to cross the tracks between the east end of the station and the junction. The two platforms are connected by an over-bridge, which also forms the approach from the down side, and which houses the booking office, ticket barriers and bookstall. There are waiting rooms on both platforms, and the down platform also has a refreshment room. Covered ways 395 ft. long have been provided on each platform. Two electric lifts are being put in to connect the platforms with the new footbridge. The public foot-bridge over the line in the London direction has been re-positioned, and from this a pathway will be formed on the up side to facilitate access to and from the new station. The existing road to the electric control room has been extended and widened to form a temporary roadway to the new station. A new signal box is located at the east end on the up side, and replaces the previous Swanley Yard and Swanley Junction boxes.

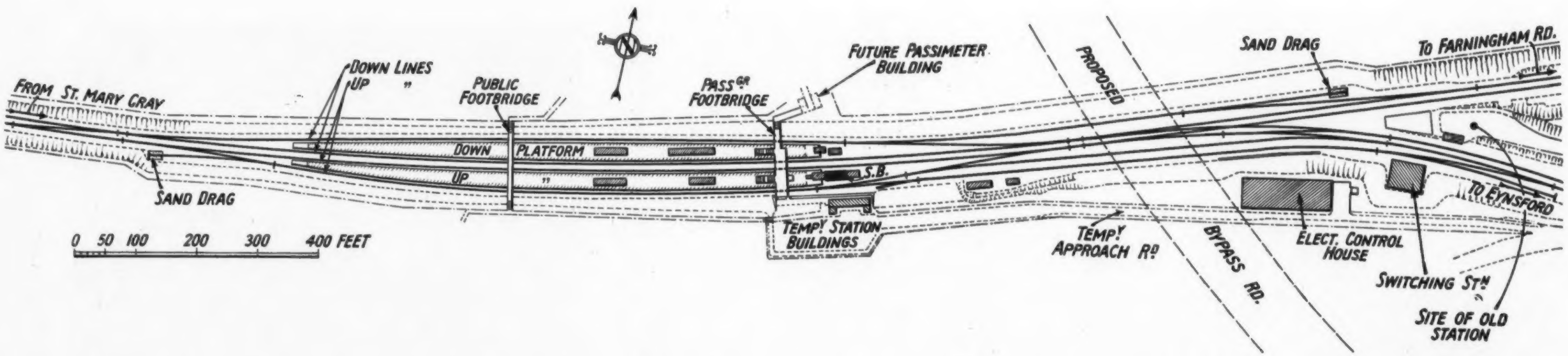
Strood Junction

At Strood Junction the up and down platforms have been extended round the curve at the north end to a total length of 600 ft., and the platform roofing on each side is to be lengthened to 260 ft. The layout of tracks and sidings between the up loop platform and the southern portal of Strood tunnel has been rearranged, and this, with the extension of the platform length, has necessitated the extension of the subway between Station Road and the station approach. New station buildings are to be constructed.

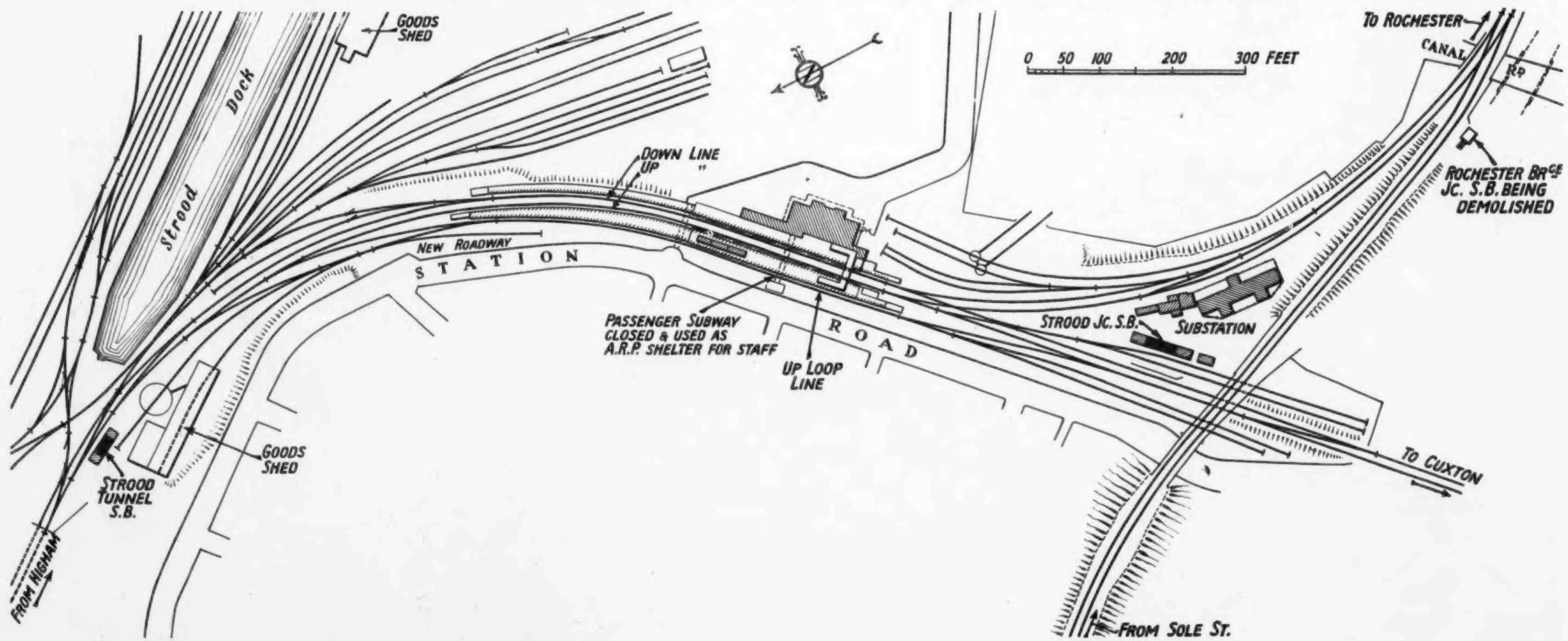
Previously there was no direct communication between the Maidstone branch and the up North Kent main line, trains from that direction having to pass through the loop platform. The tracks at the Southern end of the station have been completely rearranged to give a direct connection, and to give connection from the up and down lines to the down side carriage berthing sidings without fouling the Chatham lines. A new signal box has been built



Laying the tracks in the cutting between Swanley junction and the new station



Plan of the new Swanley station, located west of the junction, which replaces the old four-platform Swanley Junction station. The switching station has been moved from the site of the present station to the site of the old up branch platform of the Junction station



Layout of the reconstructed station at Strood, with lengthened platforms and improved connections to the Maidstone line

at Strood tunnel and another at Strood junction; the latter is on a piled foundation and replaces an old box on nearly the same site and also the Rochester Bridge Junction box which controls the Chatham and Sole Street tracks. The substation, Stroud Junction box, and a new lobby for the carriage cleaners and permanent way staff are located in the triangle between the Strood, Sole Street and Maidstone lines.

Minor Works

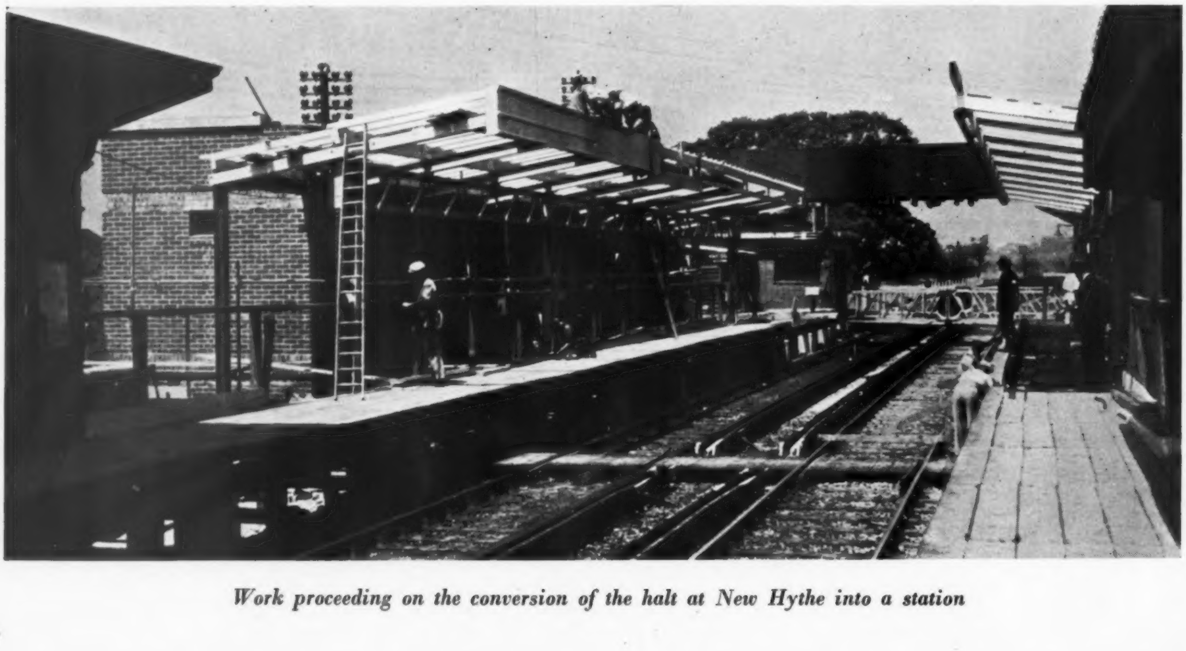
The minor alterations begin as far away as the London termini, and continue down the North Kent line to Gravesend. At Holborn platforms 1 and 5 have been lengthened to take eight-car trains and No. 1 platform track has been electrified. At Cannon Street two more platform tracks (Nos. 6 and 7) have been electrified and at Charing Cross, Waterloo and London Bridge minor signalling alterations have been necessary. In order to take the 9-ft. stock which is to work over the new electric lines, various parapets and walls have had to be set back on the routes from Borough Market junction to Gravesend *via* Bexleyheath and *via* Deptford and Woolwich. The platforms at Gravesend Central have been lengthened at the west end, and in Chatham, Fort Pitt, and Gillingham tunnels a large number of additional refuges have been provided.

On the Maidstone East to Otford and Strood to Swanley lines little has been done at the intermediate stations beyond providing new footbridges (concrete at Kemsing, Wrotham, and Barming, and steel at Fawkham) and raising the platform levels, but on the Strood to Maidstone West section new goods loops and sidings have been put in at Snodland and Cuxton to deal with the cement traffic. A new station with two 540-ft. platforms and 100-ft. platform roofing has been erected at New Hythe in place of the old halt, and the work for this had to be carried on without interference to traffic, either through or stopping. There are also a new signalbox, footbridge and mechanically-operated level crossing gates at this station. At Maidstone Barracks station both platforms have been rebuilt, and one up and four down berthing sidings, complete with cleaning and lighting facilities, have been erected. These cleaning stages, like those at Maidstone East, are supported on concrete posts of the pattern used to carry

Extension of underbridge at Cuxton necessitated by the provision of additional freight facilities

the 33 kV cables between the substations. At Maidstone West the tracks have been altered, the down platform rebuilt and raised in height, the old locomotive yard sidings rearranged and the turntable removed. A centre berthing track between the two platform lines has accommodation for an eight-car train.

Somewhat greater modifications have been made at Maidstone East. Here a new down bay platform has been constructed and both bay roads have been electrified. There is also an up berthing siding with cleaning stages, and a centre road between the two platform tracks on which a four-car train can be berthed. The up and down bay platforms and the up siding take only four-car sets, a longer track being impracticable because of a girder bridge



Work proceeding on the conversion of the halt at New Hythe into a station

General view of Maidstone East station, showing raised platforms and the electrified centre road which can be used as a berthing siding

carrying the line over the Medway outside the station. A car cleaning and inspection shed of the usual pattern has been erected on the up side at Gillingham, and has four 820-ft tracks. The framing is of steel covered with Big Six corrugated asbestos sheeting with ample glass lighting. The equipment includes hot and cold water supplies, vacuum cleaning plant for the car interiors, and a complete drainage system on the floor. Outside is a carriage washing machine with tracks so arranged that a 12-car train can be washed either on entering or leaving the depot. Here also are three electrified berthing sidings with cleaning stages. One down and two up sidings have been electrified at Gillingham, and two sidings electrified and various permanent way modifications carried out at Chatham.

Other civil engineering work included the conversion of all the station lighting from gas to electricity, the erection of the substations—of which Denton, Higham, and Strood are on piled foundations—the erection of the track-paralleling huts, the extension of Swanley control room, the re-siting of the switching station, the laying of 117 miles of conductor rails, the construction of cattle guards at level crossings and the provision of special fencing along the electrified route. The signalling is described in a separate section.

★

Rolling Stock

A TOTAL of 76 two-car trains has been built at the Eastleigh and Lancing works of the Southern Railway for the new extension. In view of the outer-suburban, rather than suburban, character of the services, a corridor has been introduced in half of the stock. Each twin-car set comprises a motor third of compartment type and a composite driving trailer with side corridor and lavatory accommodation, but without vestibule connections. The right type of accommodation thus is provided both for the short-distance passenger and the traveller who is going from end to end.

The motor-coach has a motorman's compartment, a 13-ft. guard's and luggage room, and seven third class compartments seating five passengers a side. The driving trailer has a motorman's compartment, four first class compartments seating three a side, four third class compartments seating four a side, and a lavatory. The seating capacity of a twin-car set is thus 24 first class and 102 third class on a tare weight of 76 tons. As the stock has an overall body width of 9 ft. compared with 8 ft. 6 in. of the previous stock used for the electrified lines in this district, greater comfort being given to the passenger on these outer suburban lines by reason of the greater space available, and this is enhanced by the breadth of the compartments, 6 ft. 3 in. in the thirds and 7 ft. 2 in. in the firsts.

Mechanical Portion

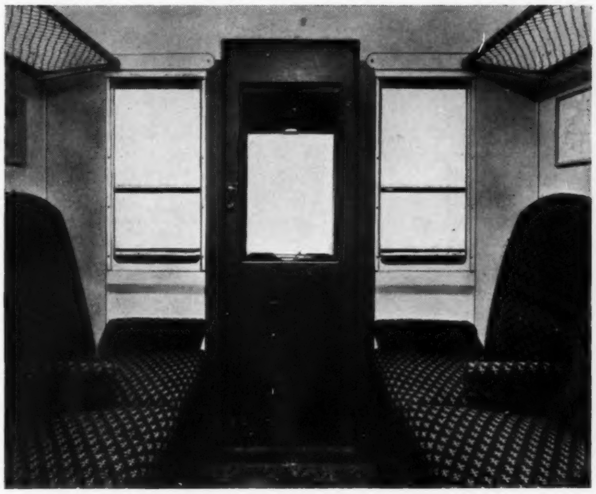
Both types of coach have a body length of 62 ft. 6 in. and bogies pitched at 44 ft. centres. The motor bogie and the outer bogie on the driving trailer, which carries current collectors, have a wheelbase of 8 ft. 9 in. and the two inner trailer bogies have a base of 8 ft. Existing standard designs are used in each case. Steel sections of special form are used between the vertical pillars of the car bodies, in order to take full advantage of the 9 ft. width. Apart from the motorman's compartments, which are constructed of rolled steel sections and steel panel plates entirely welded up, the body is built up on a framework of hard wood, with timber floors and roofing, and steel outer panel plates and doors. The coaches have been constructed to the standard 9 ft. contour but the windows have large radii to give added strength to the sides of the vehicles and to facilitate cleaning. As the width of the stock prevents the use of side look-outs for the guard, duplicated periscopes have been fitted in the roof. The underframes are built up of rolled steel sections riveted together and are fitted with self-contained anti-collision buffers having india-rubber springs; there is a central buffer of the usual type between the two coaches of a set, and the jumper connections and other details are standard.

Interior Layout

Distinctive schemes of interior decoration for the first and third class compartments have been obtained by using leather grain nut-brown Rexine for the doors, partitions and sides up to the lower light rail. This colour is either complementary to, or in harmony with, the upholstery material. The partitions above the seats, quarter panels, and ceilings are covered in pastel shades of matt-finish Rexine toning with the trimming material. For the first class compartments the shade is lichen green and a stone shade is used for the thirds. The advertisement frames are covered unobtrusively in Rexine of the same shade as that used for the partition. The cord used for the net racks matches the surrounding Rexine but relief and utility is afforded in the thirds by covering the net rods either a darker green or a nut-brown Rexine.

Uncut dark jade green moquette bearing a small *fleur-de-lys* design is used for the first class compartments and a feature of the construction of the seats is that each passenger has a separate seat cushion and back, the latter being divided by lifting arm rests; at the compartment sides fixed arm rests are provided. In the third class compartments two designs of velvet moquette in warm shades of brown with Renaissance designs of darker shade are used. The seats in the third class compartments have scalloped backs, thus clearly indicating to the passengers the regulation number of seats provided in the compartment; fixed arm rests are arranged at the compartment sides. Granite design linoleum is laid on the floors of both the first and third class compartments but the first class are also provided with hair woven rugs with borders

New 550 h.p. two-car train for outer suburban services, viewed from the driving trailer end



Interior of first class non-smoking compartment in the corridor driving trailer

Interior of third class compartment in the corridor driving trailer

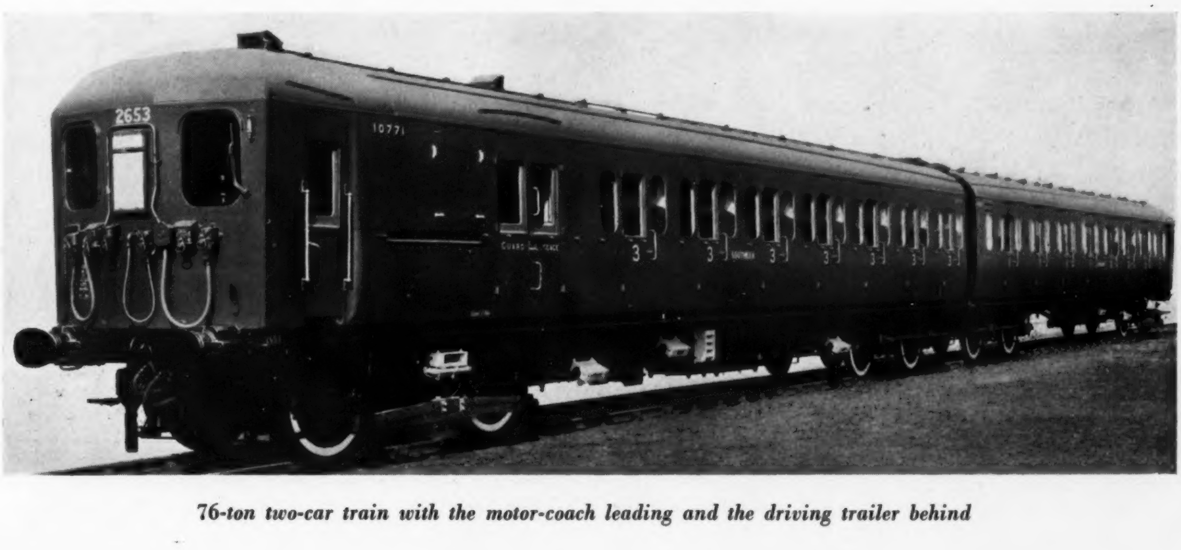
in two shades of green and mottled brown centres embodying the colours of the upholstery and the nut-brown Rexine.

In accordance with the Southern Railway's recent practice, the doors are fitted with frameless glass weatherproof droplights having locks with inside actuation in the compartments, and to prevent draught, rubber door welt strips are also fitted. A torpedo ventilator is fitted in the roof of each compartment with hit-and-miss control which can be actuated by passengers. Lighting is provided by two 60-watt lamps situated in the ceiling of each compartment. All metallic fittings are stove-enamelled or spray-painted to suit the colour scheme, but where such fittings are likely to be handled, they are of polished brass. The passenger communication chain pulls are sunk in the ceiling panels above the outside doorways.

The corridor in the first class section is finished in Indian laurel, and in the third class section in mahogany with panelling in the lower portion of nut-brown Rexine. The lavatory compartment is cream colour throughout and wherever practicable Rexine has been used. The metallic fittings are either of stainless steel or are chromium-plated. Electric heaters are fitted so that hot and cold water can be obtained. The flooring is of Terrazzo mosaic.

Electrical Equipment

The electrical equipment comprises two of the standard nose-suspended motors, with an individual one-hour rating of 275 h.p. at 27 m.p.h., and mounted on the outer bogie of the motor-coach; traction control of the electro-pneumatic unit-switch type carried below the underframe; and low voltage control circuits fed from a potentiometer. The control is arranged to multiple with the 660-volt suburban electro-magnetic control equipment by means of four small train line contactors on the motor-coach, and fitted with electro-pneumatic control. The control equipment is practically identical with that of the express stock built within recent years, and the line switches, reverser, and main contactor groups are interchangeable, and the main resistances are built up of the same mounting details and grids, although, of course, the ohmic values of the actual resistance steps differ in the two equipments.



76-ton two-car train with the motor-coach leading and the driving trailer behind

Signalling Arrangements

A COMPREHENSIVE scheme of resignalling has come to be recognised as one of the regular accompaniments of each extension of the Southern Railway electrified lines. Yet the physical nature of the routes, and the class of traffic operated over each differ so much as to make anything in the way of a standard arrangement out of the question. The change-over to electric traction on the Swanley—Gillingham and Gravesend—Maidstone lines provides an interesting case in point; the traffic hardly warranted a big outlay on continuous colour-light signalling, but on the other hand modification of the existing arrangements was desirable if the full advantages of electrification were to be realised.

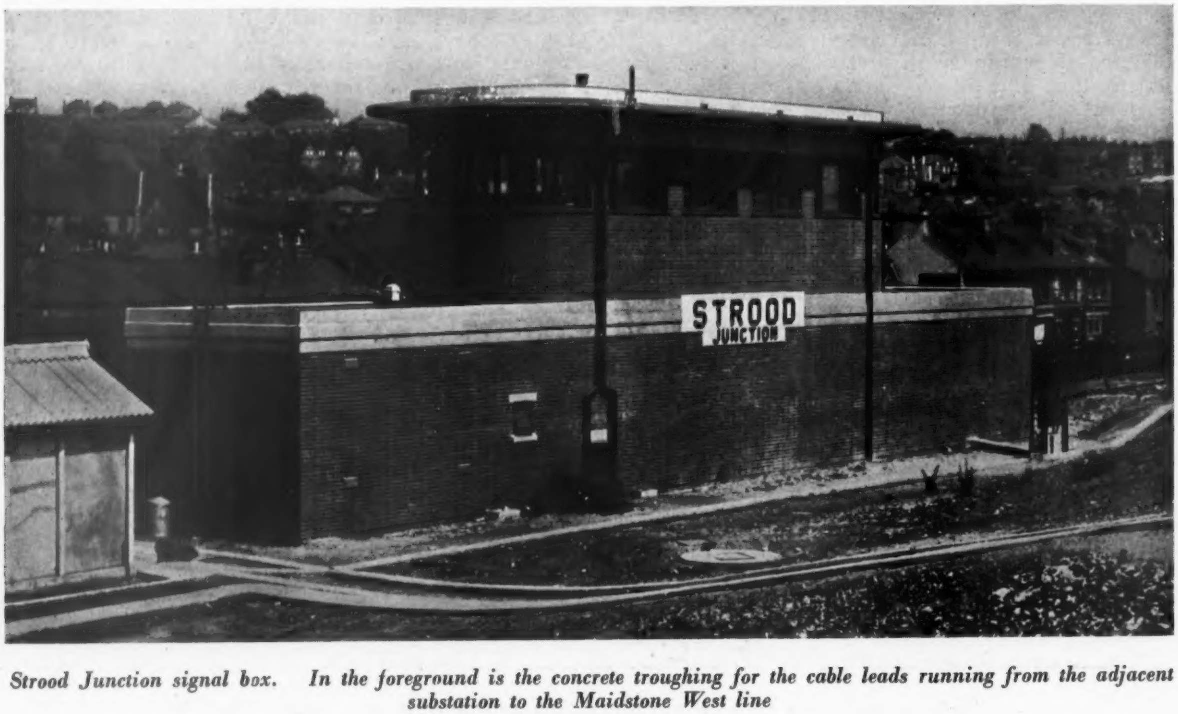
On the Kent Coast main line between Swanley and Gillingham there are operated in addition to the new electric services a number of steam-hauled express passenger trains, and owing to the gradients the speed of these trains at many points is less than that of local electric trains; on the other hand there are other locations, such as Farningham Road, where it is usually much higher. Apart from such considerations as these, signalling alterations had to be planned with the eventual electrification of the whole Kent Coast main line in view. So changes are mainly confined to the sections of heaviest grading; here intermediate section colour-light signals have been installed to preserve a headway as even as possible. These new signal locations have a neat and compact appearance; the tubular signal masts are mounted on the tops of the apparatus cases, the latter in accordance with previous Southern Railway practice, being wired and fitted up complete in the manufacturers' works.

Track Circuiting

On the lines from Gravesend to Maidstone West and from Otford junction to Maidstone East little additional signalling was necessary. As far as steam-hauled express passenger trains are concerned the latter section is used by only a few regular services of comparatively light formation; the heavy boat expresses diverted *via* Maidstone at times of pressure on the Tonbridge main line are not sufficient to call for special signalling arrangements. Throughout the whole group of lines, however, complete additional protection at and near stations has been provided by track circuiting. In all, **210** new track circuits have been installed, excluding the special sections associated with the new intermediate colour-light signals on the main line between Swanley and Gillingham. All these track circuits are of the a.c. condenser-fed type, working in conjunction with impedance bonds. Track circuiting has formed one of the major signalling works, for electrification has necessitated the replacement of a large number of d.c. circuits by others of the a.c. type, and these, with other entirely new equipment, have required the expenditure of about **£64,000**.

Resignalling at Swanley and Strood

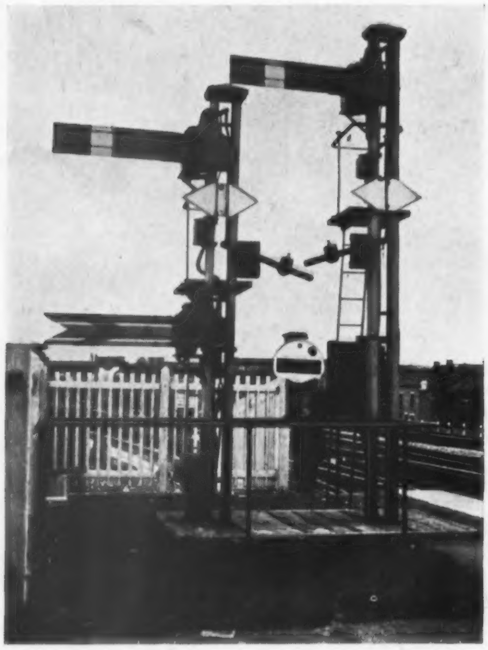
At Swanley and Strood, where the stations have been reconstructed, the signalling is entirely new. Both layouts are operated from mechanical locking frames. That at Strood has two signal boxes, Strood Junction with **70** levers and Strood Tunnel with **40** levers. The layouts are track-circuited throughout, and by means of electric lever locks and circuit controllers driven off the lever tails a complete scheme of electric track and indication locking is carried out. The points are electrically detected. The signals are mostly upper-quadrant semaphores, the distants being operated by electric signal machines. Power operated points are to be found in only a few instances where the distances from the respective signal box are great. At Strood the curved nature of the line makes sighting of



Strood Junction signal box. In the foreground is the concrete troughing for the cable leads running from the adjacent substation to the Maidstone West line

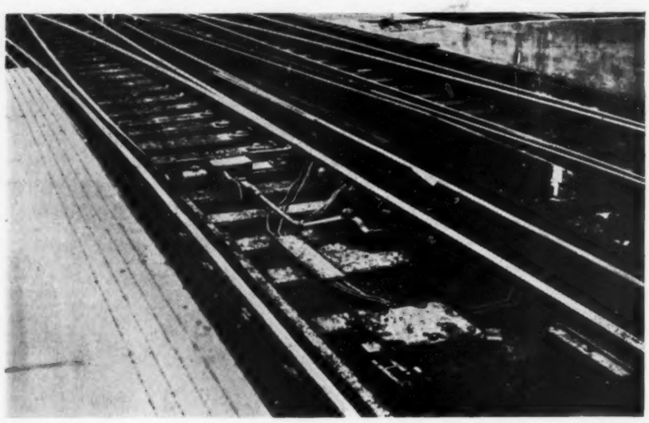
Interior of the new signalbox at Swanley, showing illuminated track-circuit diagram and track layout

Interior of Strood Junction signalbox, located where the Chatham and Maidstone West lines diverge



Left: A typical group of semaphore signals at Strood. Circuit breakers are fitted to the arms for arm proving. An electric motor operates the distant arm, and the group also includes a coloured-bar shunting signal.

Below: Layout of mechanically-worked points with electric detection; near-by is a standard impedance bond



some of the semaphore signals difficult, and banner-type repeaters, internally illuminated, are installed at various points. Mention must also be made of the improvements effected in Chatham Down Goods signal box, located between Strood and Rochester. Here the existing locking frame has been used, but it has been completely equipped with electric lever locks and circuit controllers; an illuminated diagram is included in the new equipment.

Some interesting work is to be seen at Swanley. The track layout on both down and up sides is so arranged that a train standing in any of the platform roads can be passed by a following train. The signalling is designed to give the fullest information to a driver, or motorman. For example, if a train is standing at the down main platform a following train for the Chatham line, routed *via* the down loop, is advised of a clear road through the station area by the appropriate one of three splitting distant signals; this practice of providing splitting distants for all diverging routes is in effect equal to using a long range route indicator. This layout requires an 80-lever locking frame, and the associated illuminated diagram covers a section of automatic signals between Swanley and St. Mary Cray, in addition to certain outlying points operated by ground frames. Swanley is one of the key points of this electrification scheme, and every effort has been made to give the signalman as full information as possible as to approaching traffic. The new signal box, like those at Strood Junction and Strood Tunnel, is one of the imposing modern design seen at important points on the mid-Sussex line; inside each the disposition of the apparatus is such as to make for easy and efficient maintenance.

Sundry minor signalling alterations have been made at Holborn Viaduct, Charing Cross, Cannon Street and London Bridge stations in order to provide more expeditious working of the more frequent electric train service now operating in that already very densely-trafficked area, and this work includes track-circuit modifications.

Contractors

Asea Electric Limited : H.T. switchgear and supervisory control equipment.

British Insulated Cables Limited : L.T. cables and track bonds.

British Thomson-Houston Co. Ltd. : High-speed circuit breakers.

Chloride Electrical Storage Co. Ltd. : Substation and control room batteries.

English Electric Co. Ltd. : Electric train equipments.

W. T. Henley's Telegraph Works Co. Ltd. : Multi-core cables.

Pirelli-General Cable Works Ltd. : H.T. and pilot cables.

Metropolitan-Vickers Electrical Co. Ltd. : Lamps.

Taylor, Tunnicliff & Co. Ltd. : Third rail insulators.

Westinghouse Brake & Signal Co. Ltd. : Signalling equipment; brake equipment.

Edmundson's Electricity Corporation Ltd. : Control room and substation lighting.

W. T. Glover & Co. Ltd. : Train equipment cables.

Beckett, Laycock & Watkinson Limited : Door window fittings and sliding door gear.

Hallam, Sleigh & Cheston : Light frames and rubber fittings.

Geo. Spencer, Moulton & Co. Ltd. : Self-contained buffers.

I.C.I. (Rexine) Limited : Rexine.

Edward Lloyd Wallboards Limited : Hardboard.

Steel, Peech & Tozer : Wheels and axles.

Taylor Bros. & Co. Ltd. : Wheels and axles.

Leeds Fireclay Co. Ltd. : Lavatory fittings.

Guest, Keen, Baldwins Iron & Steel Co. Ltd. : Steel plates.

N. F. Ramsay & Co. Ltd. : Door locks and fittings.

Joseph Kaye & Sons Ltd. : Door locks and fittings.

J. Summers & Sons Ltd. : Steel panels and sheets.

Baldwins Limited : Steel panels and sheets.

Hubbard Bros., Basingstoke : Route indicators and light-frame retaining strips.

J. Westwood & Co. Ltd. : Miscellaneous steelwork.

Concrete Piling Co. Ltd. : Concrete piling foundations for substations.

C. Richards & Sons Ltd. : Conductor rail fishbolts.

Wraysbury Sand & Gravel Co. Ltd. : Shingle, sand and ballast.

Guest, Keen & Nettlefold Limited : Screws and bolts, &c.

M. T. Shaw Limited : Supply of steelwork for station footbridges.

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SUPPLEMENT TO THE RAILWAY GAZETTE

DIESEL RAILWAY TRACTION

Published every Fourth week

FRIDAY, JANUARY 20, 1939

FLUIDRIVE IN RAIL TRACTION

Some of the Railways using Vulcan-Sinclair Fluid Couplings or Voith system converters in Diesel Locomotives and Railcars.

		Locos.		Railcars.
British Empire.	Great Northern Railway (Ireland)			●
	Great Western Railway			●
	London, Midland & Scottish Railway	●		
	L.M.S. Northern Counties Committee.	●		
	New South Wales Government Railways		●	
	New Zealand Government Railways	●		●
	Nizam's State Railway			●
	Queensland Government Railways	●		
	Sudan Railways	●		
	Tasmanian Government Railways			●
Continent of Europe	Belgian National Railways			●
	Czechoslovak State Railways			●
	French State Railways			●
	German State Railway	●		●
	Italian State Railways			●
	Netherlands Railways Company	●		●
	Northern Railway of Spain			●
	Norwegian State Railways			●
	Polish State Railways			●
	State Railways of the Kingdom of Jugoslavia			●
	Swiss Federal Railways			●
	Varberg—Borås—Herrljunga Railway, Sweden			●
South America.	Argentine North Eastern Railway			●
	Buenos Ayres and Great Southern Railway	●		●
	Buenos Ayres Midland Railway			●
	Buenos Ayres and Pacific Railway			●
	Buenos Ayres Western Railway			●
	Central Argentine Railway	●		●
	Entre Rios Railways			●
	Guaqui-La Paz Railway	●		
	Peruvian Corporation	●		●
Africa and Asia.	Egyptian Delta Light Railways			●
	Netherlands East India State Railways			●
	South Manchuria Railway			●

The Fluid transmissions in service or under construction for Diesel locomotives and railcars as at December 31st, 1938, comprise:—

	No.	H.P.	Largest Units.
Vulcan-Sinclair Couplings *(with change speed gear boxes and mechanical drive)*	**1,194**	**165,298**	380 H.P.
Voith System Converters *(with mechanical drive)*	**665**	**168,725**	1,380 H.P.
	1,859	**334,023**	

Of these, the orders placed during the year 1938 were as under:—

	No.	H.P.
Vulcan-Sinclair Couplings	350	46,172
Voith System Converters	337	69,695
	687	115,867

Advt. of Hydraulic Coupling & Engineering Co., Ltd., Fluidrive Works, Worton Road, Isleworth, Middx., England.

THE RAILWAY GAZETTE
A Journal of Management, Engineering and Operation
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DIESEL RAILWAY TRACTION

SUPPLEMENT

From

January 20 to December 22

1939

LONDON
33 TOTHILL STREET, WESTMINSTER, S.W.1

GENERAL INDEX.

*[Illustrated articles are indicated thus *]*

For the convenience of those who do not bind back copies, the following table shows the numbers of the pages contained in each issue of the *Diesel Railway Traction Supplement* from January 20 to December 22, 1939 :—

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Diesel Railway Traction

THE FUTURE

WITHIN the past decade every succeeding year has shown greater numbers of diesel railway vehicles set to work and ordered than in the preceding year (in **1938** there were over **1,300** locomotives and railcars introduced), and although, taking the world as a whole, there seems to be a correspondingly increased potential demand for the year **1939**, there are obvious signs that industry as a whole is nearing a critical point. Manifestations in the railway world include the closing of **2,700** miles of line in France in the **12** months since the French railways were nationalised, on the instructions of the Minister of Public Works and in an endeavour to make the railway system pay its financial charges, with little thought, apparently, of the desires of the public for whom the railways essentially exist. In America, despite diesel traction and faster and more comfortable trains, the financial plight of the railways is desperate, although the majority of the lines are efficiently run. Firm enquiries such as those for the **64** diesel shunters for the Argentine State Railways, and for further diesel railcars for the Buenos Ayres & Pacific Railway have come to nothing because of exchange situations and general economic insecurity. Rationalisation schemes, including some involving diesel builders, have been pushed further ahead, although there is no fundamental difference between rationalisation and nationalisation, both seeking to eliminate the competition of independent businesses. Finally, the Square Deal in this country is simply another sign of two forms of transport fighting for an amount of traffic not big enough for both, although the potential traffic is big enough to keep all forms of transport operating at full pressure.

Fixed Charges

The object of industry, which is to provide goods and services as and when required, appears to have been quite forgotten. With the tremendous progress of science and engineering during the **38** years of the present century, life, and the survival of any and every industry perversely becomes more uncertain, less satisfactory, and more strenuous. The public is not getting the full benefits of such advances as the railcar, the oil engine, the diesel shunter, and air-conditioning, to mention but a few; nor is the owner getting anything tangible out of them. By such means, the operating charges of railway after railway have been materially reduced, but the net revenues show no signs of the permanent improvement which should correspond. No one who has examined the cost sheets of a diesel locomotive or railcar can fail to notice the extremely large proportion which fixed charges (interest, sinking fund and depreciation) bear to the whole. In Ireland these fixed charges represent **35** to **37** per cent. of the gross operating cost of certain successful diesel cars; in Hungary, the fixed charges of local railcars average **30** per cent., and in Sweden **25** to **30** per cent., and for bigger railcars in Denmark **30** to **35** per cent. With heavy oil-electric shunting locomotives these charges vary from **28** to **47** per cent. of the gross operating cost, *i.e.*, for one quarter to one half of the accounting cost nothing tangible whatever is obtained. Serious proposals to operate heavy passenger traffic on one English line by diesel trains showed that the operating expenses, including maintenance and repair, but excluding fixed charges, could be reduced to **12d.** per train mile from **21d.** with the existing steam traction. Calculations also showed that if the line was abandoned altogether the railway would still have charges amounting to the equivalent of **12d.** per mile referred to the existing train mileage.

The Export Trade

There is just now an intensifying struggle by firms in practically every industry to obtain purchasing power by the manufacture of so-called capital goods or by capturing a share of the export market. The export of goods to compete with the output of other countries is the prime incentive to military warfare, and, as every country becomes more and more industrialised, progress towards it is seen to accelerate. The much-lauded desire to export has its root in no physical circumstances, for we in this country, for example, have a great need for most of the things we export, including a few hundred railcars and oil engines, and we are not merely exporting our surplus. Export trade, which has now attained, to quote the poet Flecker, " a monstrous beauty not unlike the hindquarters of an elephant," is forced upon us, as it is on industries in other countries, only by a defect in our cost-accounting system.

Diesel traction is in the van of engineering progress as a means to the desired end of giving rapid, frequent, cheap and reliable transport to all the traffic offering, whether existing or potential. For that reason it is not lagging behind other peaceful industries; but though it has a thoroughly sound and firm technical basis, it shares with other industries an unstable basis under the present system of counting the money costs. Unless its fundamental defect, which is manifested in what Mr. Harold Macmillan recently called " the gap between costs and purchasing power," is rectified, the diesel traction industry must necessarily slump, just as steam locomotive building—to quote one example—has slumped. Rationalisation and retrenchment will not solve the problem, and the attempt to overcome the difficulty of shortage of purchasing power at home by selling abroad what cannot be bought here is economic war, the next step beyond which is *war*. Engineers and industrialists should not shut their eyes to this. Under a system in which the present almost unlimited production of all kinds of useful goods and services was made freely available, the diesel traction industry would boom to a well-nigh inconceivable extent, and it would not be subject to constant set-backs because of international or exchange situations. Nor would there be any necessity for manufacturers to carry on cut-throat competition in order to obtain work at any price, and thus cover some of their overhead charges.

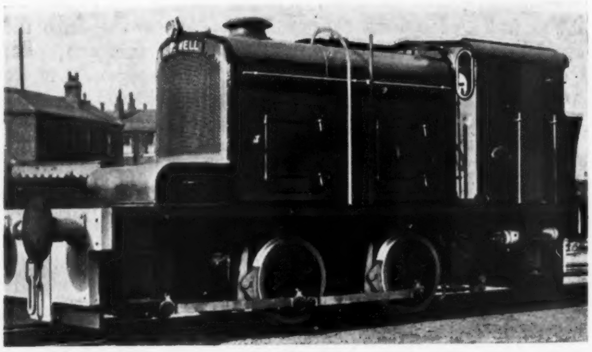
The Year's Activities in the British Isles

Construction for the home market far outweighed by orders completed and booked for export

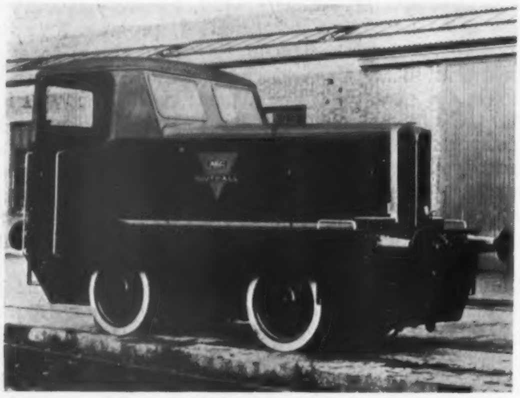
FROM the point of view of English builders, 1938 was probably a good deal better than any preceding year, although unfortunately most of the business done was for export; we in this country could have done with all the 99 Drewry cars shipped to Argentina, for example. The total value of the diesel railcars, trains, and locomotives completed in the British Isles during the past twelve months could probably be assessed at about £800,000, of which half is represented by the Drewry order already mentioned. Contracts booked during the year were fewer, and their monetary value is little more than half that of the 1938 deliveries.

A good deal of the home business must be credited to such departments as the War Office and Air Ministry, for which numerous diesel-mechanical shunting locomotives were built by Barclay, Hunslet, Hudswell Clarke, and Robt. Stephenson & Hawthorn's, the powers ranging from 100 to 200 b.h.p. A new design of shunting locomotive, available either with a 78 or a 115 b.h.p. engine, was introduced by A.E.C. Other locomotives for shunting and light service, such as the English Electric locomotives for Brazil and Hunslet locomotives for light tracks, are noted elsewhere in this issue. One interesting delivery of the year was the Wickham power bogie with supercharged Saurer engine and Cotal gearbox supplied to the Peruvian Corporation for installation in a steam railcar being rebuilt as a diesel. Further exports included ten twin-car trains built by the Birmingham Railway Carriage & Wagon Co. Ltd. for the B.A. Midland Railway; eight 100 b.h.p. Drewry cars for the Entre Rios Railway; Drewry power bogies and light locomotives for Australia, Tasmania, New Zealand and Argentina; Leyland power-transmission equipments for Ireland and Australia; and Walker cars for Peru.

The principal orders placed were by the L.M.S.R. for 20 shunting locomotives of 375 b.h.p., with English Electric power and transmission equipment; 20 railcars of 220 b.h.p. by the Great Western Railway to A.E.C. designs; ten 275 b.h.p. cars by the New Zealand Railways with the Vulcan Foundry; and a dozen railcars by the South African Railways with Metro-Cammell.

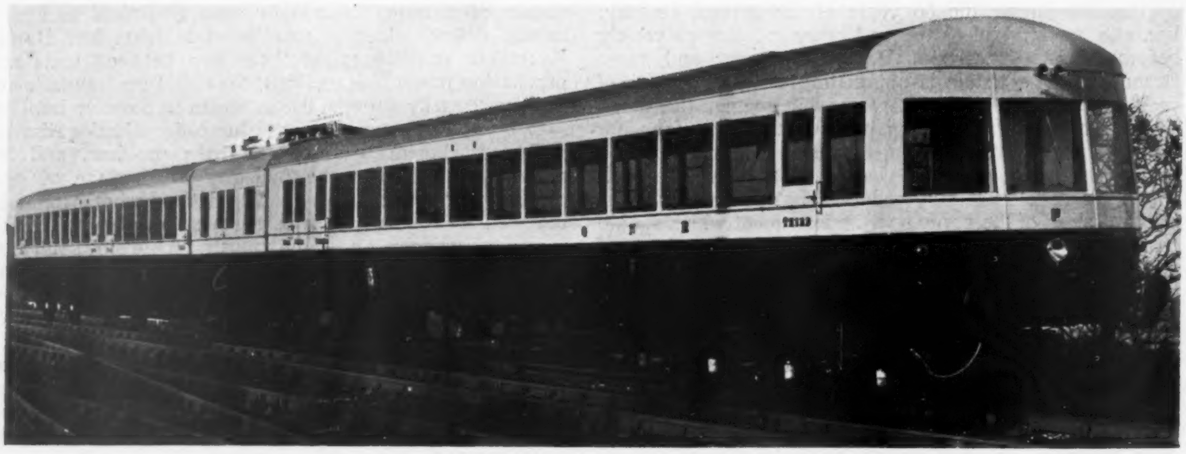


Above: 150-b.h.p. locomotive with Gardner engine and a Tele-change traction-type gearbox, built by Hudswell, Clarke for the Llandarcy plant of the Anglo-Iranian Oil Company



Left: 78-b.h.p. yard shunter built by the A.E.C. A more powerful type, of 115 b.h.p., is available also

Below: One of the two 200-b.h.p. triple-car suburban trains set to work on the Great Northern Railway of Ireland in March and April, 1938. To the end of that year the aggregate mileage was over 110,000



MULTIPLE-UNIT TRAINS

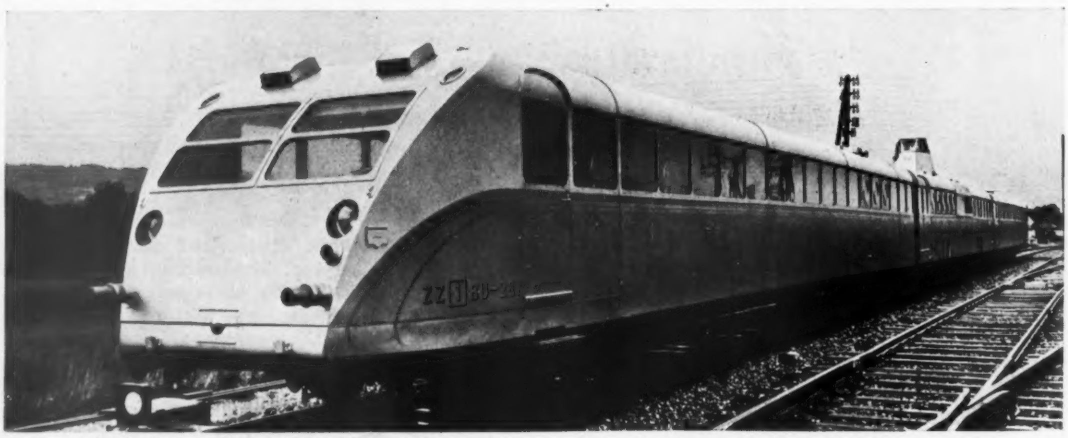
Rapid development of two-car to five-car train sets suitable for coupling up in multi-unit, and for super-speed, express, and suburban services was a feature of 1938

THE recent progress of the multi-car train has been principally along three lines, *viz.*, high-speed main-line services, such as the extension of the German *schnelltriebwagen* and the Paris—Strasbourg Bugattis; the slower speed train of much bigger formation, such as the Dutch sets, which are being supplemented by 20 new five-car trains of 1,800 b.h.p.—an advance on the original 40 three-car 820 b.h.p. sets of 1934; and on overseas lines, where, as on the Central Railway of Brazil, the Tunisian, Sorocobana, and the Argentine State Railways, diesel trains of two or three cars assure *de luxe* and semi-*de luxe* services at a far higher speed than could be maintained by steam locomotives over what is usually somewhat inferior permanent way. To a lesser extent multi-car diesel formations are also coming into favour for outer or lighter suburban traffic, *e.g.*, on the Central Argentine, Great Northern of Ireland, and Egyptian State Railways.

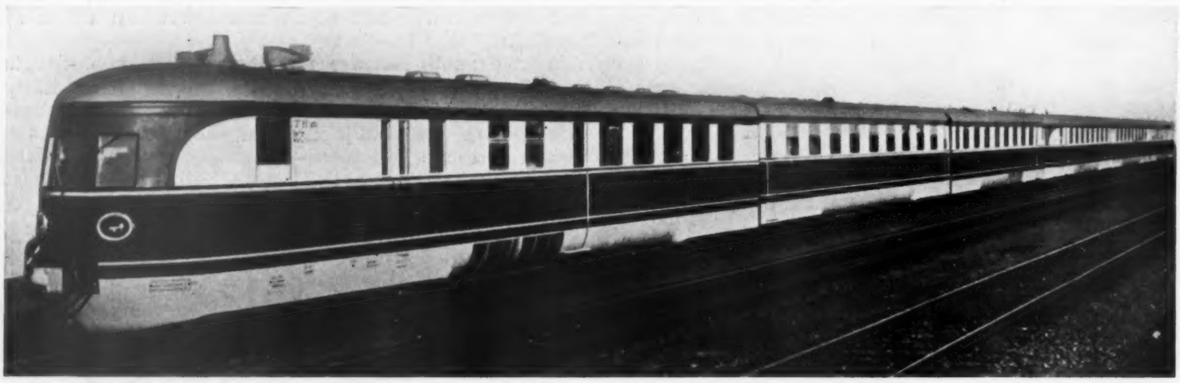
With the introduction of the 14 new triple-car trains during the summer, autumn, and winter, the German State Railway now has a total of 15 two-car 820 b.h.p. and 18 three-car 1,200 b.h.p. super-speed trains with Maybach engines, one 1,550 b.h.p. four-car train with M.A.N. main and auxiliary engines, and the experimental Flying Silver Fish, the latest Kruckenberg venture. All the two-car trains are articulated, and have open saloons; the first four three-car trains are articulated and have semi-open saloons; the four-car train and the 14 latest triple-car sets have compartment accommodation and the vehicles are non-articulated. Eight 820 b.h.p. twin-car sets with a top speed of 68 m.p.h. were also introduced to supplement the big single-unit 410 to 450 b.h.p. railcars operating the intensive and accelerated interurban traffic in the Ruhr.

It is in South America that the greatest proportionate advance has been made in the use of train sets. Early in the year the Central Argentine inaugurated a fast service with the 640 b.h.p. twin-car Ganz sets serving the district surrounding Buenos Aires, between the boundary of the electrified area and Zarate, which town is 50 miles from the Argentine capital. Three-car Ganz trains of

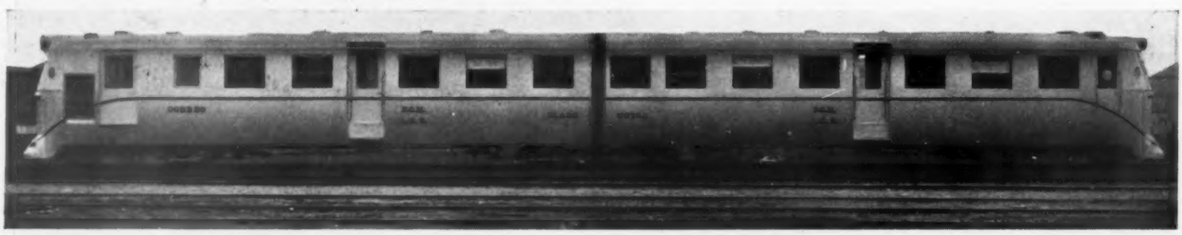
400-b.h.p. four-car English Electric train for the Colombo outer suburban services of the Ceylon Government Railways



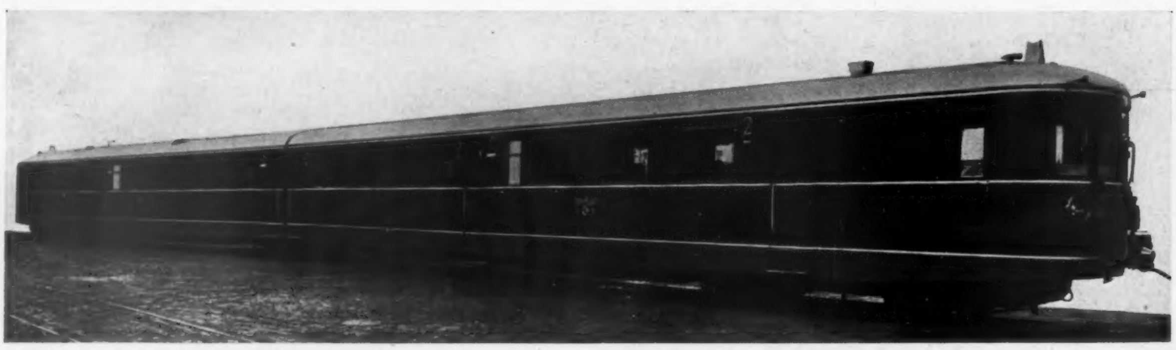
One of the new 800-b.h.p. triple-car Bugatti sets working the 70 m.p.h. Paris-Strasbourg service



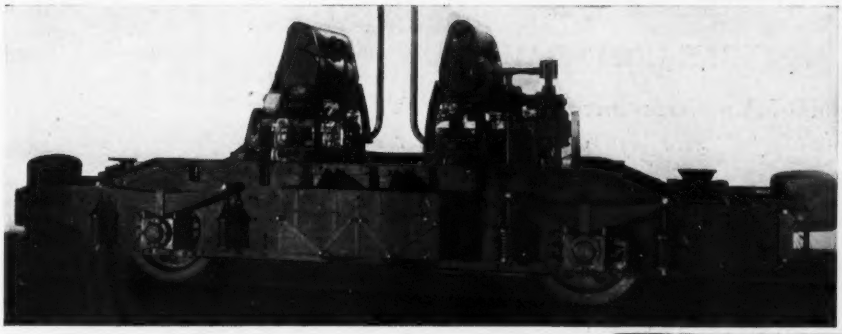
Two of the new 1,200-b.h.p. triple-car non-articulated trains of the Reichsbahn coupled in multiple-unit



Twin-car articulated double-engined 200-b.h.p. diesel-mechanical train, Buenos Ayres Midland Railway

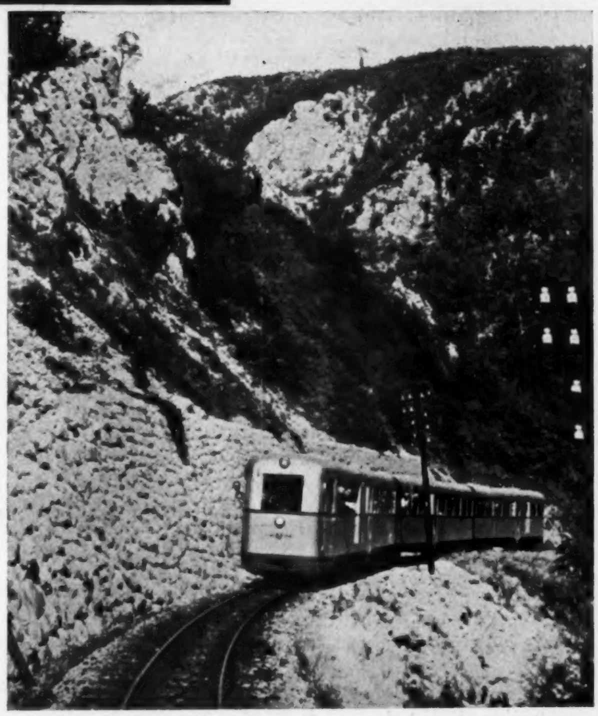


One of the eight twin-car articulated diesel-electric trains powered by two Maybach 410-b.h.p. engines set to work on fast short-distance interurban traffic in the Ruhr



Left : Power and articulation bogie, containing two Gardner 100-b.h.p. engines and Wilson gearboxes, built by Walker Bros. for the Great Northern Railway of Ireland suburban trains

Below : 480-h.p. triple-car 760-mm. gauge Ganz diesel-mechanical train, Jugoslav State Railways



similar power were set to work on the Viedma—Bariloche line, 500 miles long; they include sleeping and dining accommodation and are air-conditioned. Other trains by the same maker were set to work on up-country interurban services on the State lines, and others again are operating express buffet services on the Uruguay State and Central Uruguay Railways. The limitation of the axle load to 12-13½ tons on several of these routes made diesel formations essential if greatly increased speeds and enhanced comfort were to be obtained, as, indeed, they had to be if more traffic was not to be lost to the roads.

Similar semi-*de luxe* trains with buffet or dining car service were set to work on important interurban routes in Brazil, by five Fiat twin-car 290 b.h.p. sets on the 5 ft. 3 in. gauge lines of the Central Railway, between Rio de Janeiro and São Paulo, and by two three-car 550 b.h.p. trains on the São Paulo—Botucatu metre-gauge section of the Sorocobana Railway. Both types have mechanical transmission, and the Sorocobana trains have Deutz horizontal engines slung beneath the underframe, so that the whole floor area except the driving compartments can be given over to passenger requirements.

Long-distance traffic with very special characteristics is now being worked admirably by diesel trains in Jugoslavia and Tunis. Between Belgrade and Dubrovnik, 425 miles, and from Sarajevo to Brod, seven 480 b.h.p. three-car Ganz trains are operating at end-to-end speeds of 26-28 m.p.h. over 760-mm. gauge lines of almost unparalleled grades and curves, up to 1 in 16·6 and as sharp as 250 ft. radius, and have cut the previous best steam time by 30 per cent. thus saving a night in a train without any sleeping accommodation. The 26-28 m.p.h. average is particularly creditable over such a distance, and indeed could not be approached by steam traction, for the top speed, on even the most favourable portions of the line, is limited to 37 m.p.h. (60 km.p.h.). In Tunis, the 400 b.h.p. De Dietrich twin-car trains are giving services between Tunis city and the towns in the south of the country at speeds of 43-45 m.p.h. over metre-gauge desert lines of inferior construction, and over a distance of 263 miles. Intermediate start-to-stop schedules are as high as 52½ m.p.h.

Fiat 290-b.h.p. broad-gauge twin-car air-conditioned express diesel train, Central Railway of Brazil

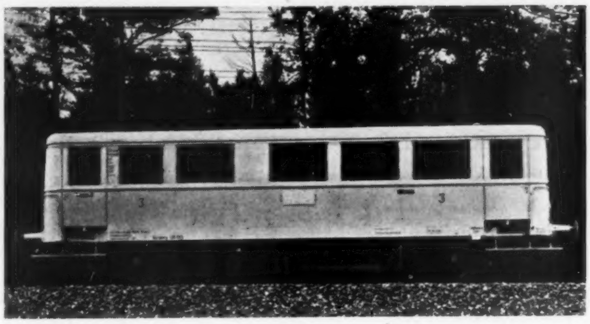
Among the diesel train sets built for suburban or short-distance work in 1938 are the two 200 b.h.p. triple-car trains of the Great Northern Railway of Ireland, in which the short centre vehicle houses only the power plants. On the two end carriages is provided a total of 164 seats in three classes. These two trains, F and G in the railway company's list, operate solely on the Dublin—Howth line, 8¾ miles long and with five intermediate stops, and average about 6,000 miles a month each. On the metre-gauge Buenos Ayres Midland Railway several of the two-car 200 b.h.p. articulated sets built in Birmingham are used for local traffic, and two of them for parcels and poultry traffic only; the remaining sets of the ten delivered include a buffet, and are used for longer-distance working.

SINGLE-UNIT RAILCARS

100 to 600 b.h.p. forms power range of wide variety of vehicles for solo operation or trailer haulage

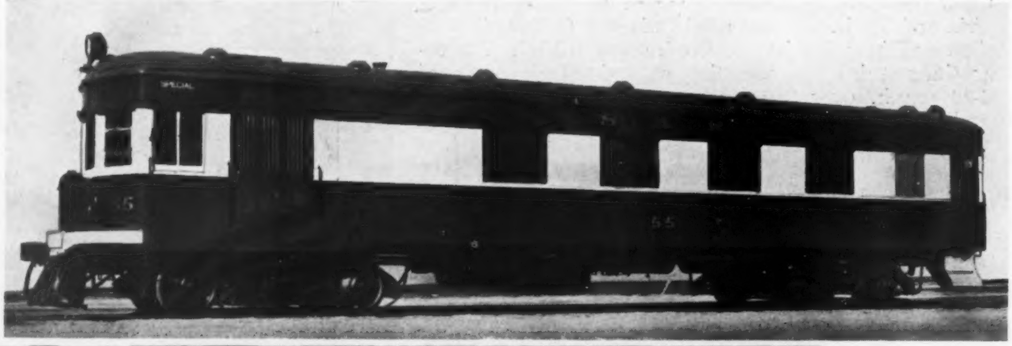
DESPITE the large number of small cars which have been built in England and on the Continent during recent months, there has been a tendency for the power of railcars to increase, sometimes simply with a view to the cars replacing light locomotives and hauling trailers, and at other times in order to be able to climb very steep grades—1 in 27 to 1 in 40—at fast speed when working solo.

A total of 13 Renault railcars, each powered by one 16-cylinder 500 b.h.p. engine, was built in 1938 for the French National Railways, and Decauville cars, each with two 300 b.h.p. Saurer engines, were also set to work. Fast work on generally level lines and "omnibus" and other trains on mountain lines form the duties of the Renault cars, which have mechanical transmission; the Decauville cars have electric transmission and have been much used on the heavily-graded Savoy line. The S.N.C.F. stock of standard cars with two bogie-mounted 300 b.h.p. engines was also increased. For single-unit cars there was a move in Germany towards the bogie-mounted slow speed engine, assisted in certain examples by the incorporation of a Büchi pressure-charger. The six-cylinder M.A.N. engine developing 360 b.h.p. normally and up to 475 b.h.p. at 900 r.p.m. when pressure-charged is a favourite. There was a revival of interest in Germany in the diesel light goods car, and 22 such vehicles were ordered; the power units are Maybach 410 and 600 b.h.p. engines. Two 240 b.h.p. diesel-mechanical luggage cars were built by Ganz for the Egyptian State Railways.

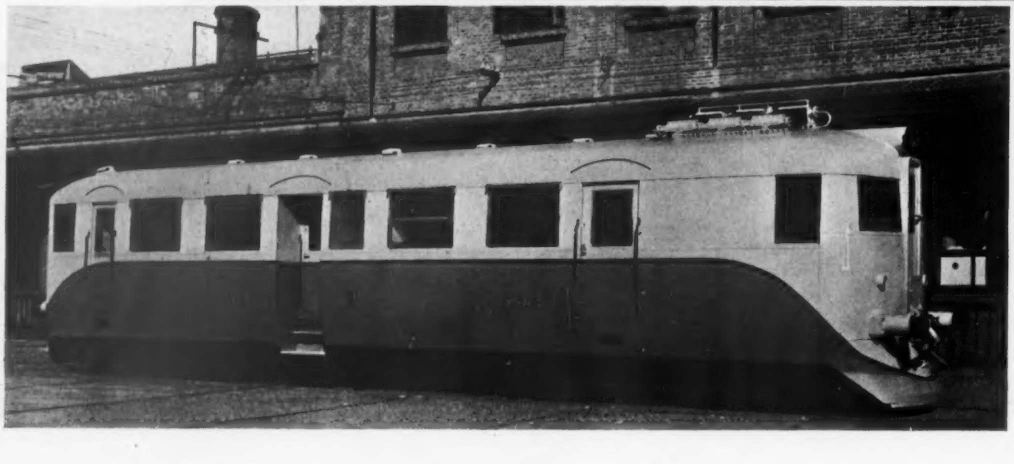


150-b.h.p. railcar with M.A.N. engine and Mylius transmission, German State Railway. Built of Hydronalium, it seats 46 passengers on a tare weight of 12 tons, and has a top speed of 46 m.p.h.

The largest delivery of the year was the 99 Drewry cars to the Buenos Ayres Great Southern Railway, and eight similar vehicles, with 100 b.h.p. engines, to the Entre Rios Railway. These cars are fitted with multiple-unit control, which is also a feature of the 50 double-engined 230 b.h.p. Fiat diesel-mechanical cars delivered to the Italian State Railways. Fiat also delivered 18 diesel Littorinas to private Italian and Italian colonial railways, and numerous Breda cars were acquired by the Italian State

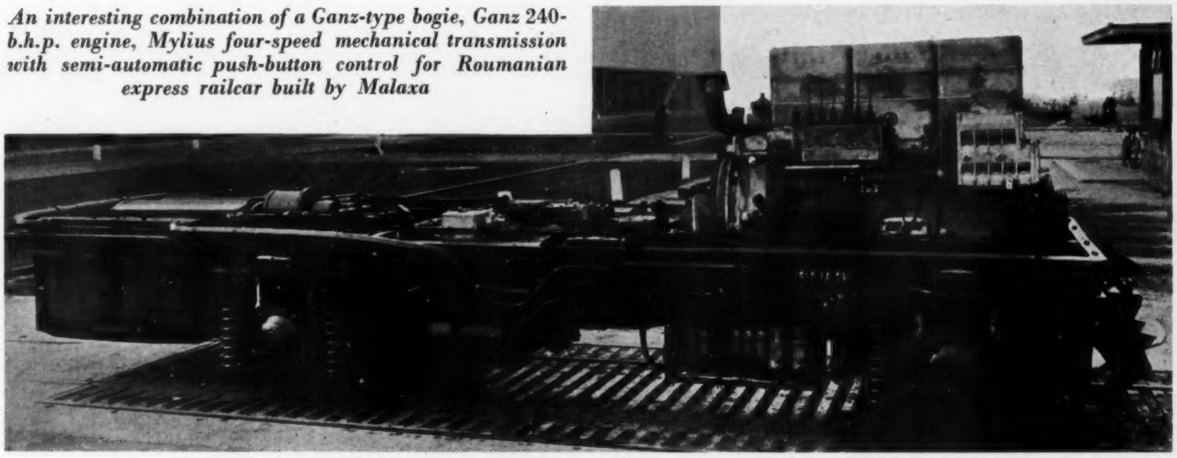


5 ft. 3 in. gauge 34-seater semi-de luxe railcar rebuilt from old petrol - engined vehicle, South Australian Railways



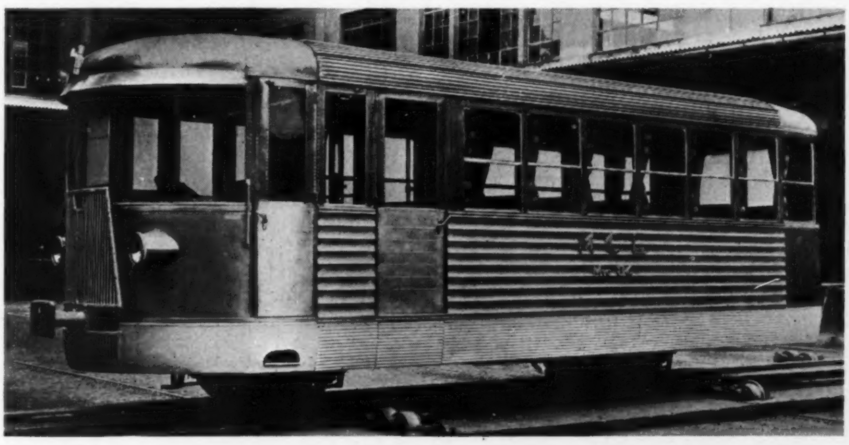
One of the 99 Drewry diesel-mechanical 100-b.h.p. railcars with Gardner engines, Wilson gearboxes and Vulcan - Sinclair fluid couplings, shipped to the B.A. Great Southern Railway

An interesting combination of a Ganz-type bogie, Ganz 240-b.h.p. engine, Mylius four-speed mechanical transmission with semi-automatic push-button control for Roumanian express railcar built by Malaxa

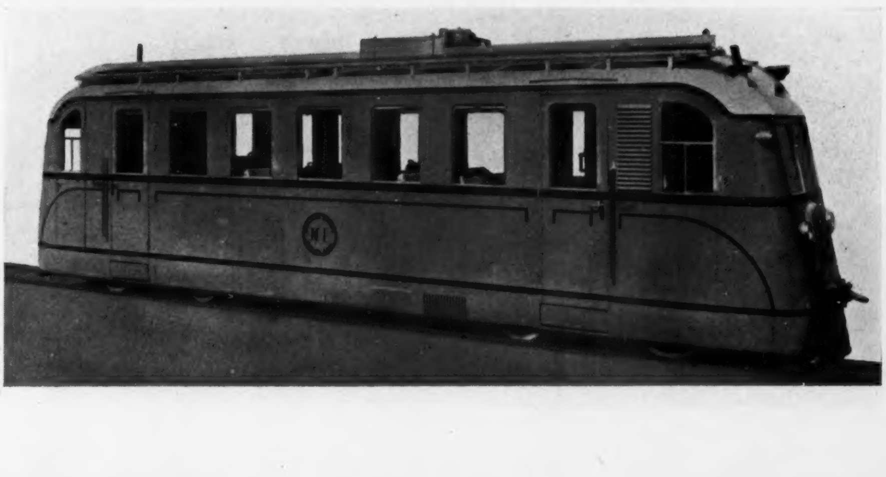


Railways. Double-bogie railcars with one or two Saurer 160 b.h.p. engines and mechanical transmission continue to be built in Poland; numerous light four-wheeled cars of 100 to 175 b.h.p. were built for the German district railways, and bogie cars up to 475 b.h.p. for the bigger German private lines; and traction by means of single cars advanced considerably during 1938 in Sweden, Norway, and the Baltic states.

Shipment of the 11 Ganz cars for the broad-gauge section of the North Western Railway of India began before the close of the year, but the straw which may show the way the wind is blowing in India was the construction in Bengal of a light four-wheeled car for the Baraset—Basirhat Railway. It is quite likely that the majority of the many small cars needed by Indian railways will incorporate English-built engines and transmissions in Indian-built chassis and bodies. The small-scale diesel car programmes carried out fairly consistently for some years in Australia were maintained, but a big advance was made in New Zealand by the introduction of the ten big double-bogie cars with Leyland engines and transmission, and there are indications that the order for the contemplated three-car diesel trains will come to an English builder. There remains to be recorded several South American deliveries, such as the Walker cars for the Peruvian Corporation, the ten 235 b.h.p. Ganz cars for the Uruguay State Railways, and sundry small cars sent to Brazil, Venezuela and Mexico.



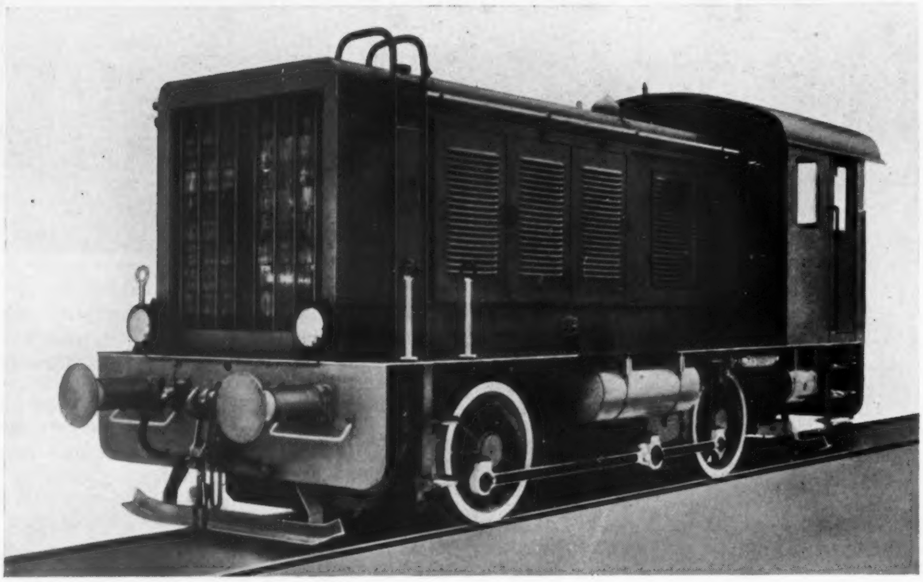
Left: One of a dozen stainless steel combined rack-and-adhesion railcars for grades up to 1 in 10 built by Piaggio for the Calabra-Lucana line. The engine is of the Brescia-Saurer type, of 130 b.h.p., and the transmission is mechanical. The tare weight of the 35-seater car is 7¾ tons



Right: 3 ft. 6 in. gauge 125-b.h.p. railcar seating 30 passengers on a tare weight of 16¾ tons, built for the Venezuela Central Railway by the Ateliers Metallurgiques à Nivelles

SHUNTING AND LIGHT SERVICE DIESEL LOCOMOTIVES

Four-wheeled and six-wheeled units of 80 to 360 b.h.p. still form mainstay of locomotive builders

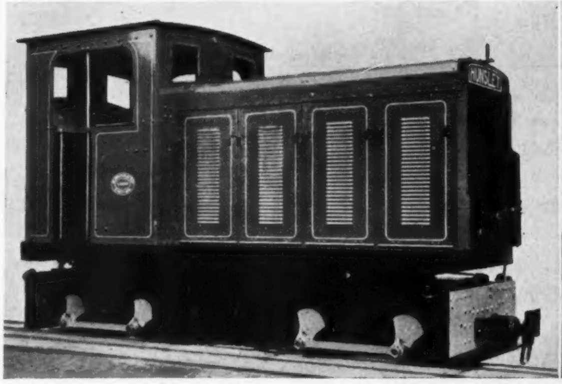


360-b.h.p. Deutz-engined locomotive with Voith hydraulic transmission

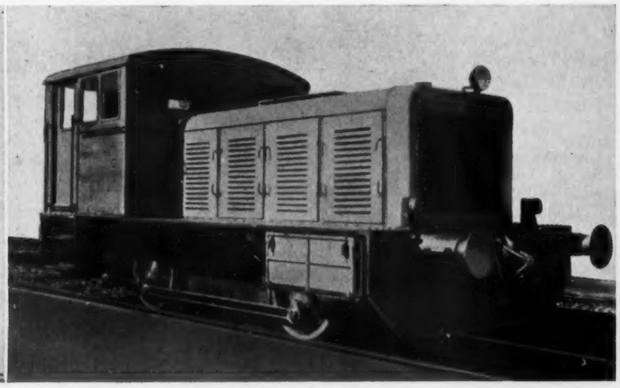
SINCE 1925 there has never been any lack of orders, taking the manufacturing countries as a whole, for diesel shunters from 20 b.h.p. upwards, but dating from the large-scale advent of the railcar in 1931-32 medium power locomotives for line service have been comparatively rare. However, during the past twelve months several interesting designs of this character have been completed or put in hand, although none of the orders is of any great magnitude. Three metre-gauge 1-BB-1 oil-electric locomotives of 450 b.h.p. were built by English Electric for the Eastern Railway of Brazil to haul light passenger trains; the weight is 55 tons and the maximum tractive effort 18,000 lb. There are two force-ventilated traction motors, each geared to one axle, and with the adjacent axle driven by a coupling rod. The only other light diesel locomotives for line service built in this country during 1938 are of small power, such as the 82 b.h.p. McLaren-engined Hunslet locomotive illustrated on the next page; It, like most of the other locomotives by this builder, has the Hunslet constant-mesh gearbox and Easy-change clutches, which are extremely efficacious.

Abroad, a number of four-wheeled and six-wheeled locomotives with 360 b.h.p. Deutz engines and Voith hydraulic drive were built by Schwartzkopff and Orenstein & Koppel for local freight and mixed trains on the Reichsbahn and other German railways, and similar-powered locomotives but with M.A.N. engines and electric transmission are being built in Roumania. For service in Eritrea, Fiat is building a locomotive powered by an engine pressure-charged on the Büchi system to raise its output from 450 to 600 b.h.p. Two 735 b.h.p. oil-electric Co-Co locomotives with Sulzer engines began service on phosphate lines

Four-wheeled shunting locomotive built by Harland & Wolff Limited for their own yard. It has a 225-b.h.p. six-cylinder two-stroke Harland-B. & W. engine and a S.L.M. oil-operated gearbox and mechanical transmission



Hunslet 2-ft. gauge light locomotive for working round 30-ft. curves. It has a 82-b.h.p. McLaren engine and a three-speed Hunslet gearbox



One of the 28 shunting locomotives with 150-b.h.p. Ganz engine and Mylius four-speed transmission, Roumanian State Railways; the weight is 24 tons

in Algeria during the autumn, over a route with grades up to 3 per cent., and lying almost entirely at 2,000 to 3,500 ft. above sea level; train weights are up to 500 tons.

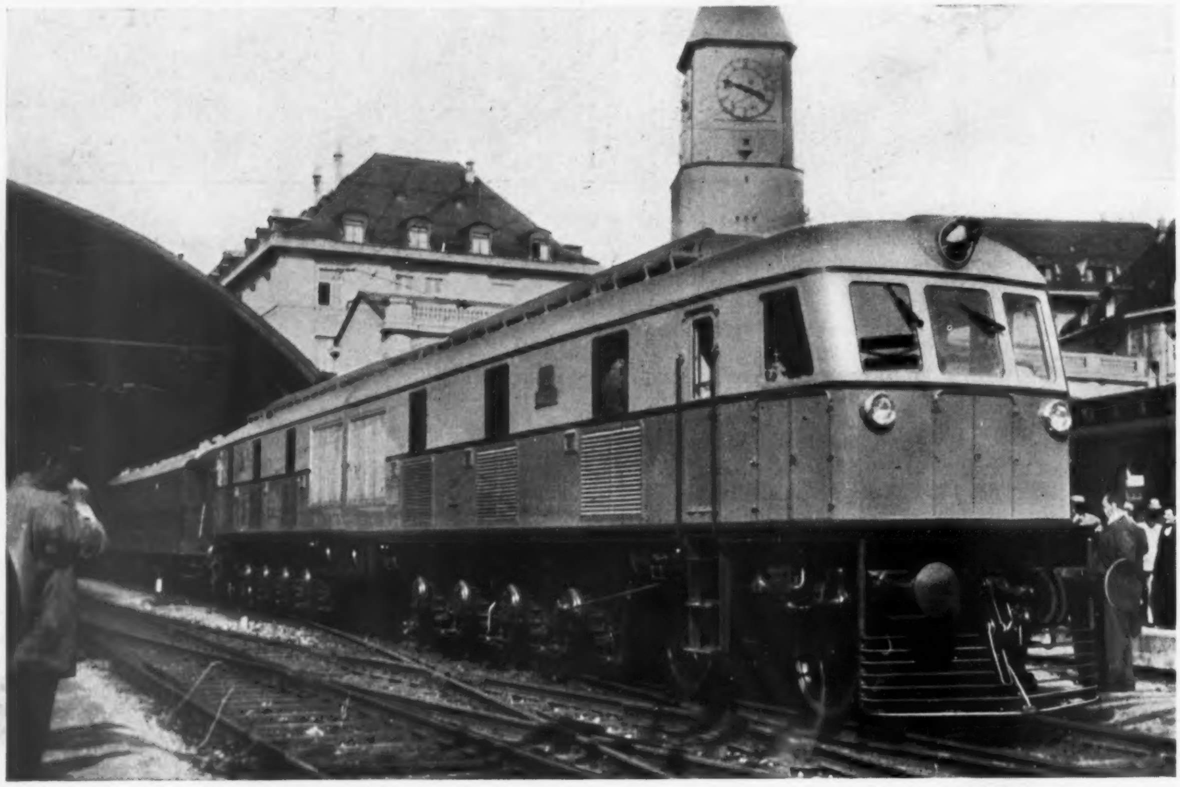
A score of 50-ton 375 b.h.p. shunting locomotives were ordered by the L.M.S.R., with English Electric power and transmission equipment, and outside the U.S.A. this formed the biggest shunting locomotive order of the year, although the Roumanian State Railways took delivery of 25 diesel-mechanical shunters of 150 b.h.p. The A.E.C. brought out its new industrial shunter design, and the usual quota of Drewry small standard locomotives was built, for places as far apart as Queensland, Argentina, India, and New Zealand. In addition to several government and industrial shunters, Barclay completed two 34-ton four-wheeled locomotives each powered by a six-cylinder Beardmore engine set to give 260 b.h.p.; actually, these engines are two of Beardmore's old 350 b.h.p. type. Deliveries made by Robt. Stephenson & Hawthorn's include some two-speed diesel-mechanical locomotives with five-cylinder Crossley engines and with a top speed of 8 m.p.h.

The numerous Fowler shunters built during the year range from 40 to 150 b.h.p., and orders are in hand for locomotives up to 150 b.h.p. and with a weight of 26 tons, which will have flameproof equipment suiting them to operation in dangerous areas. This builder specialises in the Fowler-Sanders oil engine, the design of which incorporates the results of a good deal of original research into combustion problems. Once again the ex-P.L.M. section of the French National Railways increased its stock of heavy oil-electric shunting locomotives, this time by three 600 b.h.p. Sulzer-Homécourt units intended for passenger train shunting between the Gare du Lyon and the sidings at Conflans, and also for marshalling freight trains up to 1,200 tons in weight. During the year the Argentine State Railways called for tenders for 64 diesel shunters in two classes, but the placing of the orders has been deferred, partly owing to exchange alterations. Bids were received from all over Europe and America, and the lowest tender, from an American firm, is understood to have been only half the figure of the highest offer.

31-ton Fowler diesel-mechanical shunting locomotive with 150-b.h.p. Fowler-Sanders oil engine

HIGH-POWER DIESEL LOCOMOTIVES

Tendency to develop further use of single and twin-unit locomotives of 1,800 to 4,500 b.h.p. for high-speed and heavily-graded lines



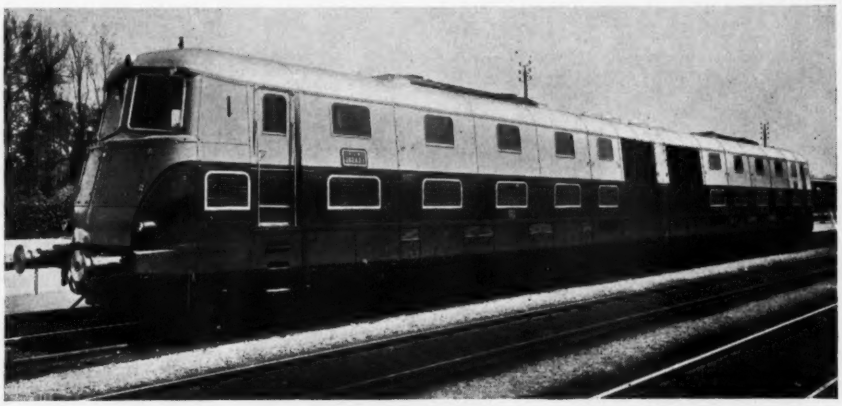
4,400-b.h.p. Sulzer-engined locomotive for main-line mountain-division service with 600-ton passenger trains on the Roumanian State Railways

THERE has been a tendency during the past two years to develop the large diesel locomotives for main-line work in powers of 1,800 b.h.p. and over, a tendency which is in contrast to the hitherto general, and as yet unabated, progress of the multi-unit train set for really fast work as well as for more normal speeds. As far as non-American practice is concerned, the culmination of the first stage in the construction of super-power diesel locomotives was reached during 1938, with the introduction of a 4,400 b.h.p. locomotive in Roumania, and the completion of the second of the French National Railways' main-line express locomotives for the Region du Sud-Est, formerly the P.L.M. The beginning of the second stage was marked by the order for a double-engined locomotive of 2,000 b.h.p. placed by the Norwegian State Railways, for this locomotive is to have one of the modern forms of hydraulic turbo transmission, whereas previous locomotives elsewhere have been equipped with electric transmission.

The first of the ex-P.L.M. main-line diesels, delivered in 1937, was put into regular operation with the inauguration of the summer timetables in May, 1938, and since that time has been making a daily return trip between Paris and Lyons, a round trip of 634 miles at an average running speed of more than a mile-a-minute with comparatively light trains. The locomotive with two of the same type of Sulzer engine set to work on the Roumanian State Railways in July has been making a daily return trip of 212 miles between Bucharest and Brassov with trains of 500 to 600 tons weight, which are hauled without assistance over the Carpathian mountain division between Campina and Brassov.

European and American high-power diesel locomotive practice, apart from the prevalence of twin-vehicle formation, offers a series of contrasts. In Europe, two or four four-stroke pressure-charged engines are incorporated; in America three to six non-pressure-charged two-strokes are used for powers of 3,000 b.h.p. or more, and two for 1,800 b.h.p. to 3,000 b.h.p. The use of the two-stroke Winton engine of 900 or 1,200 b.h.p. has been dictated probably by the desire to instal an existing engine and thus eliminate a lengthy period of experimental running, and to obviate any delay in waiting for spare parts. With the nine or ten months of experimental and only partially regular running of the first French locomotive, of quite new general and detailed design, may be contrasted the few days and weeks of some of the later American trains and locomotives, incorporating engines, control systems, and mechanical construction to well-tried designs. On the

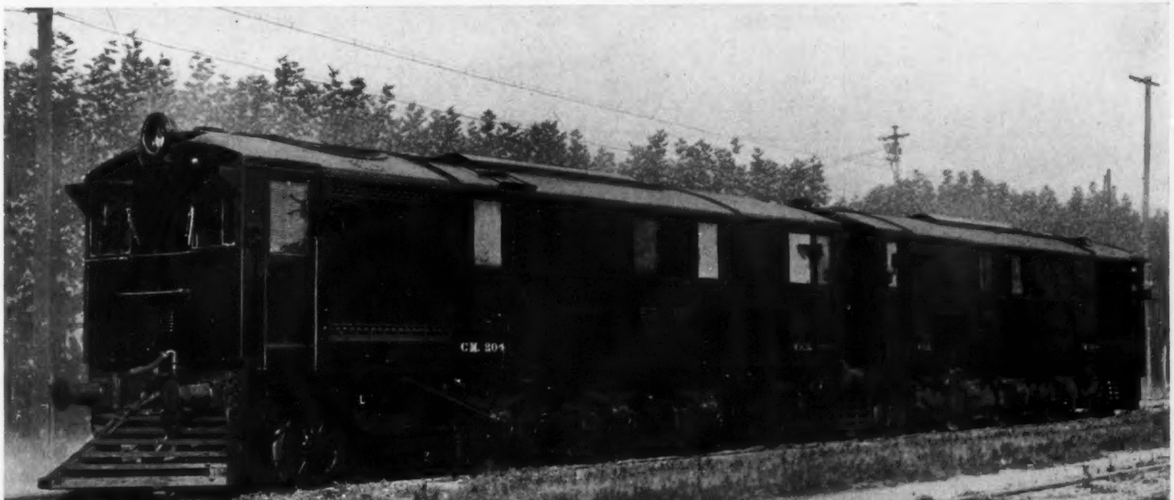
The second of the main-line diesel electric locomotives of the French National Railways. It is powered by four light-weight 1,050-b.h.p. M.A.N.-type engines, with two Saurer 130-b.h.p. high-speed engines for auxiliary power. The weight is 220 tons



other hand, in the 17-car Union Pacific trains, for example, with main engine capacity aggregating 5,400 b.h.p., there are 72 sets of cylinders and driving mechanisms compared with 24 sets in the ex-P.L.M. locomotives. Specific weights are from 110 to 120 lb. per b.h.p. in Europe and from 125 to 150 lb. per b.h.p. in America. Auxiliaries are provided with power by separate, and sometimes numerous or large, engine-generator sets in American locomotives, whereas the general practice elsewhere is to have an auxiliary generator working from the main generator shaft. But in America the auxiliary loads, by reason of the lighting and air-conditioning demands, are far higher than on the Continent.

Of the high power locomotives set to work in 1938, that for the Roumanian State Railways was powered by two Sulzer 2,200 b.h.p. Büchi pressure-charged engines. It weighs 230 tons full and 218 tons empty, has a maximum starting tractive effort of 81,500 lb., giving a factor of adhesion of 4·05 tons against the alhesion weight of 148 tons when empty, and the top speed is 62 m.p.h. At the one-hour rating the tractive effort at the wheel rims is 53,800 lb. at 20.8 m.p.h., and at the top speed the tractive effort at the rims is 21,500 lb. The second of the ex-P.L.M. locomotives is powered by four 1,050 b.h.p. S.G.C.M.-M.A.N. engines supplemented by two 130 b.h.p. Saurer auxiliary engine sets, giving a total capacity of 4,460 b.h.p. The loaded weight is 221 tons, and empty about 208 tons; the maximum tractive effort at starting is 70,500 lb. at the wheel rims, and 66,000 lb. can be maintained up to 12·5 m.p.h.; at 62 m.p.h. the maximum tractive effort available is 20,800 lb., and at the top speed of 93 m.p.h. (150 km.p.h.), 11,200 lb. The Norwegian State Railways placed an order with Krupp for a 2,000 b.h.p. diesel-hydraulic locomotive with the 1-Do-1 wheel arrangement which is to be tried experimentally on the Oslo—Bergen line before any further units are ordered. Two Büchi pressure-charged M.A.N. engines developing 1,000 b.h.p. each are to form the power machinery, in conjunction with Krupp (Lysholm-Smith) hydraulic torque converters.

Four broad-gauge locomotives were shipped to the Buenos Ayres Great Southern from the British Isles, two of 1,000 b.h.p. each by Harland & Wolff, and two of 880 b.h.p. each by Armstrong-Whitworth; the two Irish-built units have the 1-Do-1 wheel arrangement, and the two Armstrong locomotives the 1-Co-1 layout. Both types have a top speed of just over 60 m.p.h. and are equipped for working in multiple-unit. The Armstrong locomotives are those which operated three or four years ago on the 5 ft. 6 in. gauge system of the Ceylon Government Railways, and installed in each is an Armstrong-Sulzer main engine and an Armstrong-Saurer auxiliary set. As a rule these locomotives are used coupled together as one unit, handling heavy main-line trains between Buenos Aires and the southern ports.



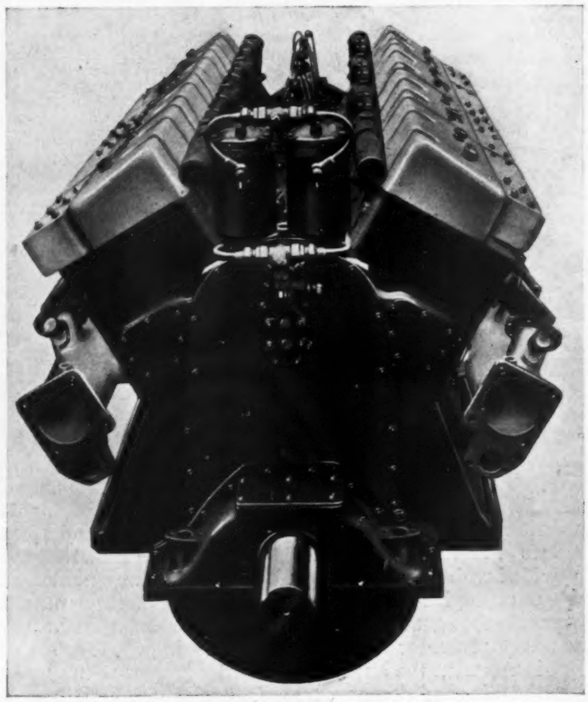
Two 880-b.h.p. Armstrong-Whitworth diesel-electric locomotives, Buenos Ayres Great Southern Railway

OIL ENGINES

Pressure-charging and weight-lightening progress bringing efficient and practical designs from 100 up to 2,200 b.h.p.

IN a branch of diesel engineering which has reached such a settled and widely-applied state as railway traction, entirely new makes of engine become rarer as time goes on, and no new maker entered the lists with actual applications during 1938, although Petter evolved a new two-stroke engine capable of being installed in diesel locomotives up to 525 b.h.p. The normal top speed of this range is 675 r.p.m.; and, as with the remainder of railway two-stroke engines, the scavenging is of the uniflow type, the inlet ports encircling the cylinder barrel and the exhaust port being located in the head.

Of notable new models by makers established in the railway field there were plenty. Paxman, for example, attained one of the highest technical pitches yet reached in high-speed engine design and construction with a 16-cylinder vee unit giving a maximum output of 1,000 b.h.p. at 1,500 r.p.m. on a specific weight varying from 6 lb. per maximum b.h.p. with normal light alloy construction to 5 lb. with a plentiful use of light alloys. Intended more particularly for light but powerful marine service, it has not yet been applied to rail traction, although its bulk, weight and general characteristics should suit it to multiple-unit train operation at a maximum governed output of 800 to 900 b.h.p., in the beginning, at least. The 16 cylinders have a bore and stroke of 7 in. by 7¾ in. respectively, and at the top output the piston speed is 2,260 ft. per min. and the m.e.p. 95 lb. per sq. in. By the incorporation of a pressure-charger the output of this engine could be raised to 1,150-1,300 b.h.p.



Paxman 16-cylinder 1,000-b.h.p. engine

Left: The cylinder liner of one of the double-piston cylinders showing inlet and exhaust ports and, in the centre, the holes for the fuel injection nozzles

Below: The gear-driven scavenging blower

C.L.M.-Junkers 500-b.h.p. two-stroke opposed-piston oil engine

The second notable high-power engine of the year was the pressure-charged 1,050 b.h.p. M.A.N. type, four of which were installed in the second of the French National Railways' 4,400 b.h.p. main-line oil-electric locomotives. Built under licence by the S.G.C.M., these engines have six 12·2 in. by 15·4 in. cylinders and give their maximum output at a speed of 700 r.p.m. Such low revolutions in conjunction with an engine weight of only 14 lb. per b.h.p. exemplify one of the principal influences of exhaust-gas pressure-charging, of which the Rateau type is used in this particular locomotive. Welded steel construction is embodied in the framing and cylinder blocks of these engines. Two very similar engines, but with Büchi exhaust-gas pressure-chargers, are being built in Germany by M.A.N. for installation in the 2,000 b.h.p. diesel-hydraulic locomotive for the Norwegian State Railways.

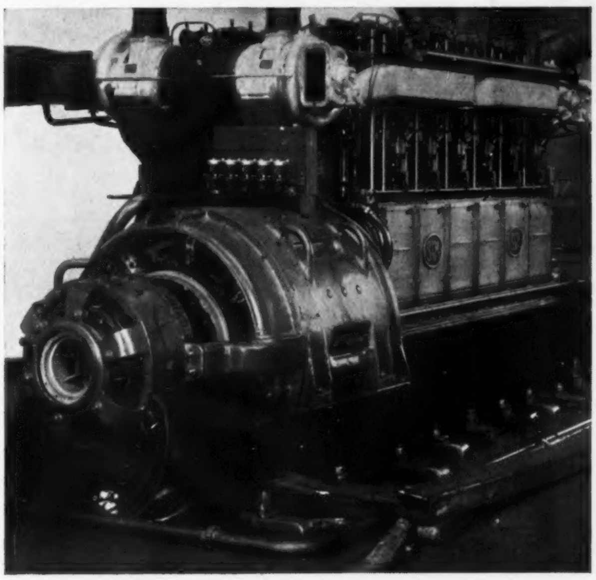
Pressure-charging, more particularly on the Büchi exhaust-gas system continued to grow apace, and there is now an equivalent total of 130,000 b.h.p. of this equipment installed in, or on order for, railway engines, over a pressure-charged power range of 125 to 2,500 b.h.p. per engine. Within the smaller power range Saurer and Simmering, among others, have used this equipment effectively; in the medium-power range the M.A.N. six-cylinder vertical 360 b.h.p. engine is used in a number of railcars with Büchi equipment arranged to increase the maximum output up to 450-475 b.h.p., and the supercharged version of the Maybach vee engine, giving 600 b.h.p. at 1,400 r.p.m. instead of 410 b.h.p., is well known; in the higher power range it is really pressure-charging which has made possible the big locomotives of the last two years, such as the Roumanian and French examples.

Among railcar engines, the French Saurer company

introduced a new six-cylinder model giving 200 b.h.p. at 1,500 r.p.m. compared with the 160 b.h.p. of the BXD engine; the new type, installed in the trains of the Tunisian Railways, has not yet been built by the Swiss parent company. The A.E.C. has greatly modified the 130 b.h.p. six-cylinder engine used in the existing railcars of the Great Western Railway, and is installing the modified type, giving 105-110 b.h.p. at 1,650 r.p.m., in the 20 G.W.R. railcars under construction. There is also talk of a Gardner 8LW engine, to raise by 30 per cent. the power range of the present LW series.

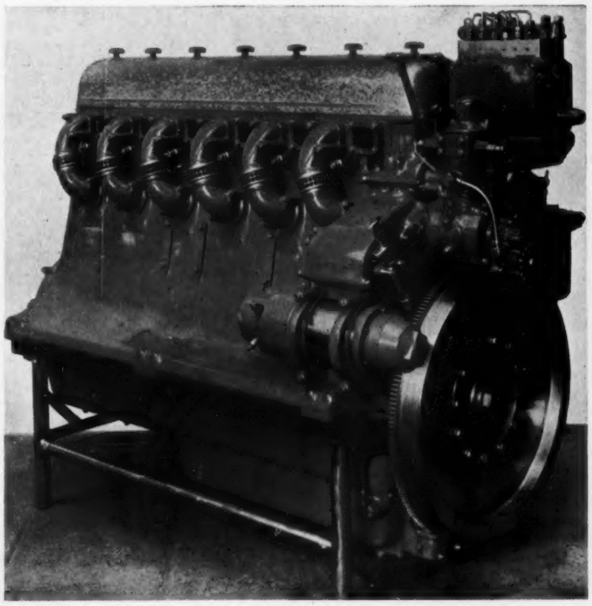
As the result of experience, and of the ensuing modifications, the output of the old Maybach 210 b.h.p. six-cylinder engines has been raised to 225 b.h.p. and to a peak output of 250 b.h.p. Similarly, the maximum governed outputs of the standard 410 b.h.p. and 600 b.h.p. Büchi pressure-charged Maybach engines have in certain recent orders been raised to 450 and 650 b.h.p. respectively. The pressure-charged 600 b.h.p. engine, at 9 lb. per b.h.p., is still the lightest engine in service.

In the two-stroke arena the counterpart of the Paxman engine in the four-stroke line is the CLM-Junkers opposed-



M.A.N. twin six-cylinder Rateau-pressure-charged engines mounted side by side with a generator at each end

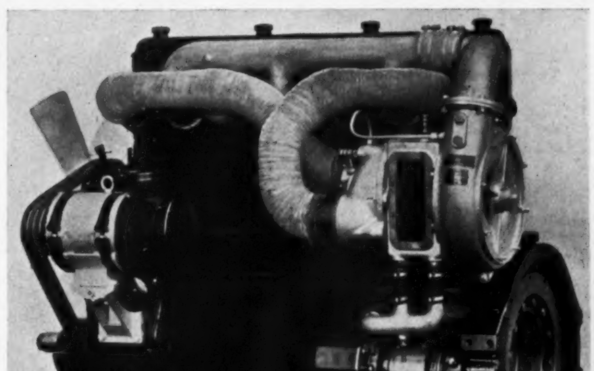
piston engine giving 500 b.h.p. at 1,500 r.p.m. on a weight of less than 10 lb. per b.h.p., and with a piston speed of 1,480 ft. per min. and a m.e.p. of 78 lb. per sq. in., pressure and weight figures well in advance of the usual railway two-stroke engine. This engine, and the four-cylinder 250 b.h.p. engine introduced in 1937, are to be used as horizontal engines, with any necessary detail changes, as well as in their normal vertical form. An extension of the Harland-B. & W. two-stroke engine is also to be noted, principally the eight-cylinder engines used in the two main-line locomotives built for the Buenos Ayres Great Southern Railway. At a speed of 800 r.p.m. each engine develops a top output of 500 b.h.p. in cylinders 7·1 in. by 11·8 in., giving a m.e.p. of 66 lb. per sq. in. and a piston speed of 1,890 ft. per min. In America, the Winton Engine Division of the General Motors Corporation made a modification to its standard 12-cylinder model by increasing the cylinder bore from 8·0 in. to 8·5 in., thereby increasing the nominal output from



Six-cylinder Maybach engine developing 250 b.h.p. at 1,400 r.p.m. on a weight of 2,900 lb.

900 to 1,000 b.h.p.; the stroke and speed are unaltered at 10 in. and 750 r.p.m. respectively.

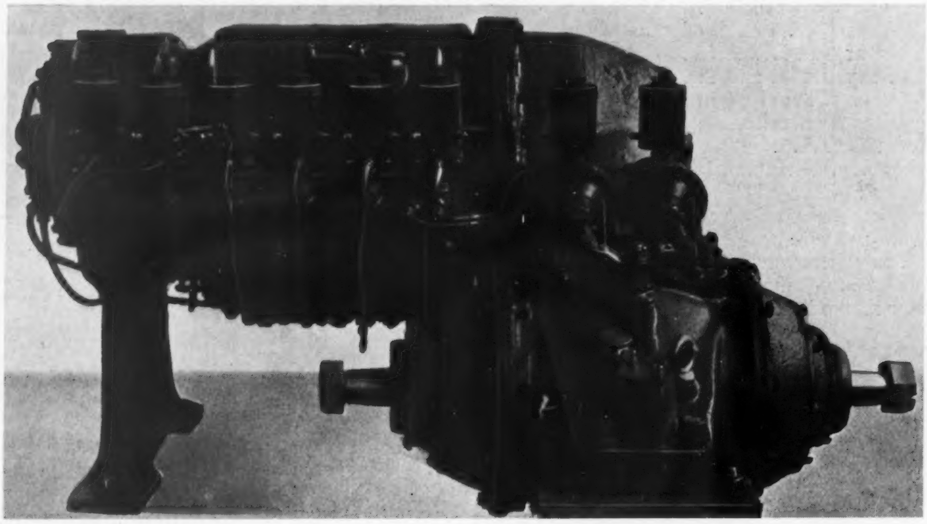
Applications of existing models during the year included another of the biggest single railway oil engine—the Sulzer 12-cylinder twin-bank Büchi pressure-charged unit, normally considered as having an output of 2,200 b.h.p., but which has given 2,500 b.h.p. at the same speed of 700 r.p.m. Other Sulzer engines, of 600 and 735 b.h.p. were installed in French-built locomotives. For shunting locomotives one of the newest of English rail traction engines, the Fowler-Sanders, was used to an increasing extent, and the applied range of another well-known model —the English Electric K type—was extended.



Saurer BXD engine fitted with Büchi pressure-charger, to give 220 b.h.p. at 1,500 r.p.m.

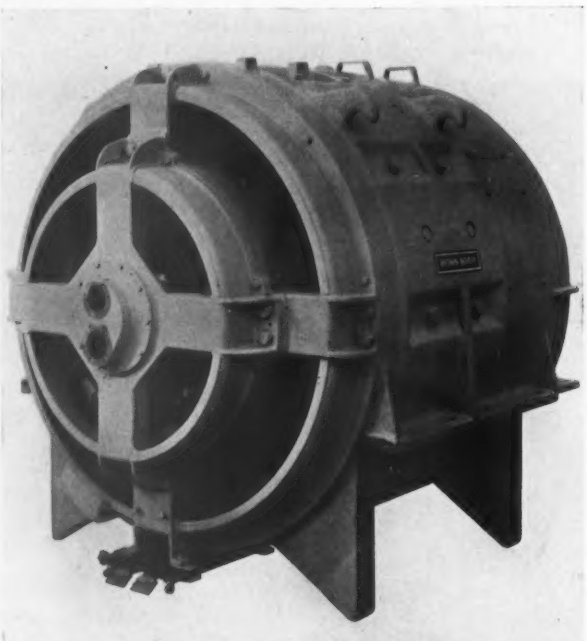
TRANSMISSION SYSTEMS

Mechanical, electric and hydraulic types all make progress towards higher power applications and towards easier or automatic control



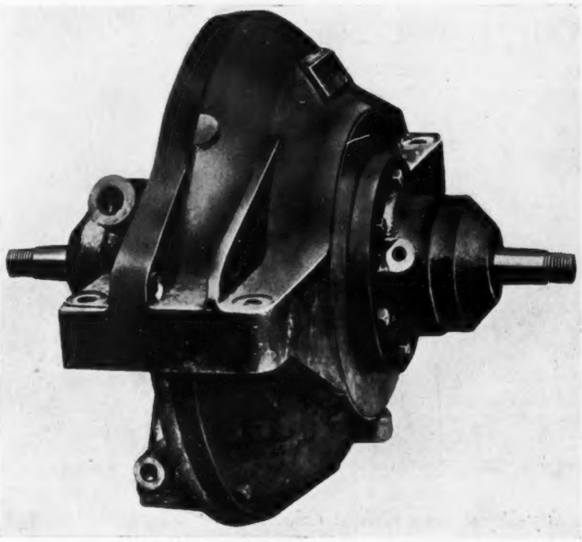
Wilson epicyclic gearbox taking up torque of 300-b.h.p. engine running at 1,150 *r.p.m.*

IT cannot be said that the progress of transmission systems during 1938 followed a course which was unexpected, except, perhaps, that proof of the wide characteristics of hydraulic transmission was given by the order to Krupp for two big sets on the Lysholm-Smith system for installation in a main-line locomotive for Norway. Hitherto the biggest Lysholm-Smith unit was for something under 200 b.h.p. in conjunction with a high-speed engine, whereas each Norwegian set is to transmit the torque from a 1,000 b.h.p. engine running at 700 r.p.m. The Voith system has already been used in conjunction with an engine giving 1,400 b.h.p. at 700 r.p.m., but most of the applications are with engines of 1,400 r.p.m. or over, although during 1938 there was an extension of its use with 360 b.h.p. engines running at 600-900 r.p.m. in four-wheeled and six-wheeled locomotives and in railcars. At the end of 1938 a total of 665 Voith and Voith-Sinclair turbo-converter sets, aggregating 168,725 h.p., were in service or on order, and no fewer than 337 of them, totalling 69,695 h.p., were ordered during 1938. The trouble-free service of the present turbo transmissions may be instanced by the performance of the New South Wales trains, which for 15 months past have operated, without any compiaints as to the transmission system, between Parkes and Broken Hill, first twice-weekly in each direction, then every day, and making a mileage of 175,800 during the first 12 months.

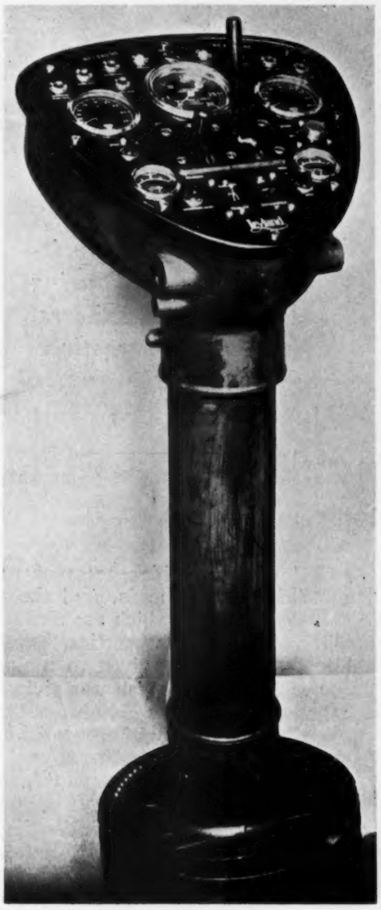


1,250-*kW. main generator and inset* 70-*kW. auxiliary generator with normal speed of* 745 *r.p.m.*

Apart from the increase in power—to 300 b.h.p. at 1,150-1,200 r.p.m. in the Wilson box, up to 420 b.h.p. at 1,400 r.p.m. in the Mylius box, to 375 b.h.p. at 1,450 r.p.m. in the SLM-Winterthur box, and the widespread use of the Ganz box at 310 to 365 b.h.p. at 1,250 to 1,450 r.p.m.—the problems and progress of mechanical transmissions in railcars and multi-car trains are now mainly in the fields of remote and multiple-unit control and in the provision of automatic control. Several semi-automatic sets of Mylius transmission—with a separate push-button control for each gear step—were installed during the year, and a fully automatic control—with but a single push-button—has been evolved by the same inventor. An automatic control has also been produced by Ardelt. Electro-pneumatic remote and multiple-unit control systems of the manual type are now used extensively



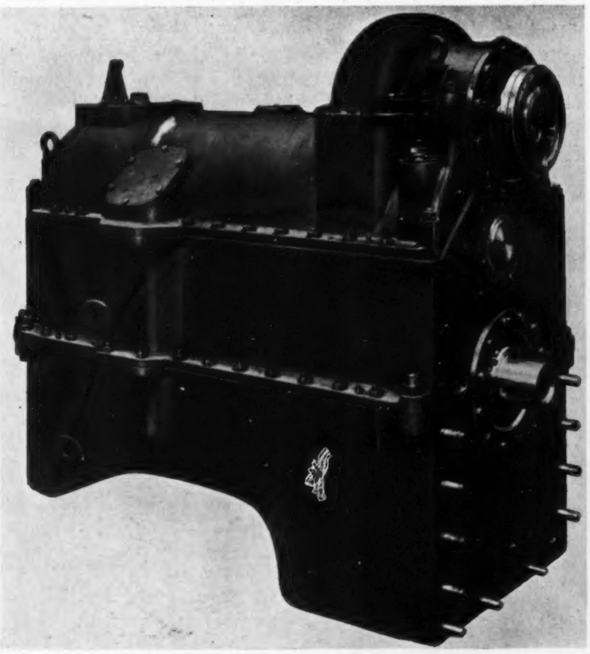
Left: Torque converter of V.S.G. (Lysholm - Smith) hydraulic transmission fitted to the 55-h.p. locomotive built for the railway at the Glasgow Exhibition



Right: Leyland control pedestal carrying all the controls for double-engined diesel - hydraulic railcar for the L.M.S.R. (Northern Counties Committee)

by Ganz, Drewry, Fiat, and Mylius, and a vacuum system is incorporated in the double-engined Buenos Ayres Midland trains built by the Birmingham Railway Carriage & Wagon Co. Ltd.

The move towards the use of six-speed to eight-speed gearboxes, which began some two years ago with the Norwegian and Maybach eight-speed units and the Minerva six-speed box, has made little further progress, although the operating advantages of numerous gear steps appears to be fairly well recognised, a notable example being the five speeds used by Ganz in the Jugoslav trains, which do not operate at speeds above 37 m.p.h., but run over a steeply-graded and constantly-varying profile more than 400 miles long. Another example is to be found in the score or so of Roumanian diesel shunting locomotives, which have four-speed Mylius boxes and a two-speed gear on the jackshaft, giving eight possible gear steps up to the maximum speed of 34 m.p.h. At the other end of the scale there is a commendable tendency to build shunting locomotives for shunting only, to limit them to a top speed of about 10 m.p.h., and to provide them with gearboxes having only two speeds.



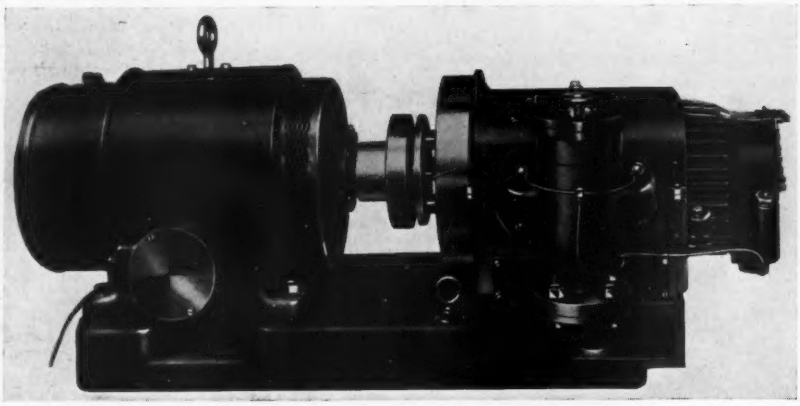
500-b.h.p. Voith turbo transmission set containing one converter and two coupling circuits

Desire to take the best of everything, and sometimes to give national industry full play, has led to some interesting power-transmission combinations, such as the 375 b.h.p. Carels-Ganz engine, Vulcan-Sinclair fluid flywheel, and SLM-Winterthur gearbox on the Belgian National Railways, and the Ganz engine with Mylius gearbox and semi-automatic control in cars built by Malaxa for the Roumanian State Railways. A new box of the year was the traction type unit with Tele-change control, evolved by the Hydraulic Coupling & Engineering Co. Ltd., and applied to several shunting locomotives built by Hudswell, Clarke.

Electric transmission nowadays is applied comparatively rarely except for high powers, or for high current with low engine speeds, as in heavy shunting locomotives. The most striking installations of the year were to the 4,400 b.h.p. Roumanian locomotive, with Brown Boveri-Sulzer servo field regulator control, and to the second 4,400 b.h.p. locomotive of the French National Railways, with the new form of Simplex-Cuenod control in which the automatic regulator is connected by a Wheatstone bridge to the engine throttle and to the accelerator handle of the main controller. Each of the two main generators of the Roumanian locomotive has a one-hour rating at 744 r.p.m. of 1,252 kW., 505 volts and 2,480 amp.; the maximum current at starting is about 3,300 amp. at 420 volts.

ENGINE AND MECHANICAL EQUIPMENT

Notes on some of the new, improved, and widely-applied proprietary details fitted during 1938 to diesel railcars, trains and locomotives, throughout the world



Northey-Boyce motor-driven exhauster set

THE extremely high rates of retardation, often from three-figure speeds, and the general desirability of light weight, which are characteristics of railcar and multi-car diesel train practice, have necessitated considerable attention being given to braking problems, particularly as equipment which was giving promising results two or three years ago has not always lived up to expectations. Control of the deceleration rate with decreasing speed was one of the first problems to be tackled when speeds advanced to the 95-105 m.p.h. mark and top-speed braking ratios of 200 to 250 per cent. became common, and apparatus such as the Westinghouse pendulum controller, the Hildebrand-Knorr electro-pneumatic device, the Jourdain-Monneret centrifugal pattern, and the Decelakron, has given efficient and reliable operation over a period.

Disappointing performance of various types of drum brakes on medium-weight and heavy-weight cars, owing mainly to overheating and distortion resulting from the large forces applied to drums of necessarily restricted size, has led to various forms of disc brakes, with Capasco or other friction linings, and to the development of very large single brake blocks or double brake blocks on the wheel rims; for example, the N.R. brake being tried on certain cars of the French National Railways has clasp rigging and two articulated shoes on each side, the rubbing surface of the top shoes being of friction material and of the bottom shoes cast iron.

All problems connected with the electro-magnetic brake have not been solved and the number of applications is not increasing very rapidly, but during 1938 a brake of this type used only at starting was introduced by Ganz on the Jugoslav trains which operate by adhesion over grades as steep as 1 in 16·6; this brake is applied to the rail during a stop and prevents the train running back when the wheel brakes are released and before the cars are properly under way.

Improvements in various directions have been made in the design and construction of compressors and exhausters for diesel vehicles. In the latest Westinghouse air-cooled type the question of silent running has been dealt with effectively. Units similar to that illustrated have been fitted to the 108 Drewry cars shipped to Argentina; although in diesel-mechanical units such a compressor is usually driven by a Brammer belt, Tex-rope, Renold chain or similar arrangement, in cars with electric transmission it is preferably driven by direct coupling to a two-speed electric motor, thus enabling it to be started at half

Maybach fan-cooled radiator for cooling water and lubricating oil. The fan is driven mechanically from the bogie-mounted engine, and the cooler set is mounted beneath the railcar underframe. The cooling set illustrated has a heat dissipation capacity of 250,000 calories an hour

speed and increased to full speed at brake release by means of contacts on the driver's brake valve. The speed range is from 200 to 1,500 r.p.m.

By a modification of the Roots blower principle—the introduction of ports in the rotors—the Northey-Boyce exhauster gives a rapid exhaustion with a reduction in resurgence and without any reduction in volumetric efficiency, which is of the order of 88 per cent. The motion is purely rotary and the shafts are carried on roller bearings; the only limitation to the speed is the size of the ports which it is possible to provide in the rotors. There are three standard sizes covering a complete range of 25 to 200 cu. ft. of free air per min. at speeds of 960 to 1,920 r.p.m.

Running Gear

Endeavours to lighten the weight have led to various forms of wheels and axles, particularly for small four-wheeled cars where a wheel and axle assembly represents a large proportion of the dead weight. The dished disc wheels, with separate tyres and hollow-bored axles, as introduced by the Uerdinger Waggonfabrik and the Bochumer Verein are much used on the Continent; one of them, as used on the Reichsbahn, was illustrated on p. 1118 of the December 23, 1938, issue of this Supplement. Other special wheels with rubber inserts to deaden noise and vibration continue to be used, such as the Bacqueyrisse wheel, by De Dietrich. Considerations of weight and curves led Ganz to adopt for one of the South American orders a six-wheel bogie in which the centre pair of wheels were flangeless and were loose on the axle, Timken taper roller bearings being carried in the wheel hubs.

Roller bearing axleboxes have long been regarded as a standard for railcars, and an increasing number of diesel locomotives are being equipped with them. The A.E.C. industrial shunter is fitted with the Timken cannon type of box, the feature of which is that the two single-row tapered roller bearings are connected by a rigid casting, so that the side thrust capacity is almost twice that of two separate boxes. The box is a steel casting split along the horizontal axis; it embraces the whole of the axle between the wheel hubs and gives stability and resistance to tilting loads. This type of box is used also in the power bogie of the Great Northern Railway of Ireland trains.

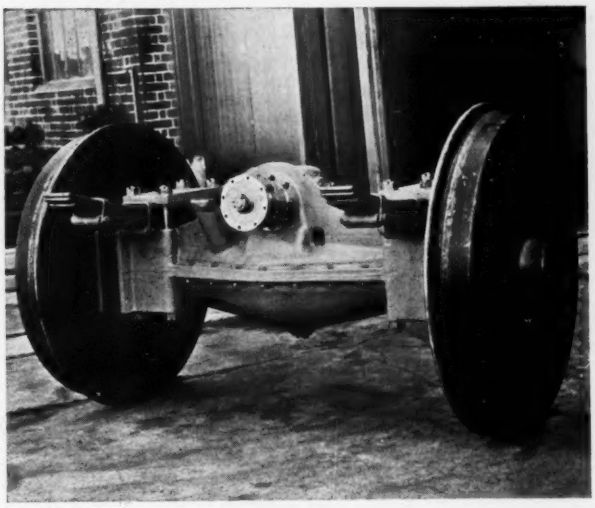
Multi-purpose automatic couplers of the Ganz and Scharfenberg types continue to be used; among the applications of the latter make were to the 14 three-car high-speed trains of the Reichsbahn and to the 52-seater 240 b.h.p. Malaxa cars for express service, with speeds up to 68 m.p.h., on the Roumanian State Railways.

Air Filtering Equipment

The extreme importance of properly filtering the intake air, fuel and lubricating oil is frequently unrecognised. In quite an ordinary atmosphere there are two grains of dust per 1,000 cu. ft. of air; allowing 3¼ cu. ft. of intake air per min. per b.h.p., a 500 b.h.p. engine running for 5,000 hr. a year in such an atmosphere would draw in 140 lb. of dust in that time. Air filters are commonly stated to be 98 to 99·9 per cent. efficient, but there appears to be no standard on which any figures are based. Moreover, the efficiency of a filter is not to be judged by the amount of dirt which it excludes but the amount which it passes; a filter with a stated efficiency of 98 per cent. is only half as efficient as one with a figure of 99 per cent. under the same conditions, for it passes twice as much foreign matter.

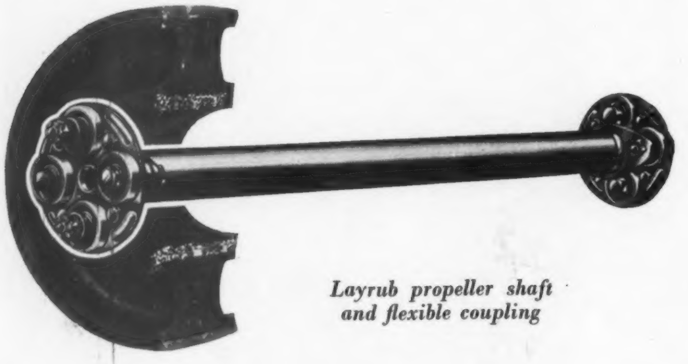
Filters of both the dry and wet types are in use for intake air. In the Vokes Protectomotor dry pattern a large filtration area, up to 200 times that of the air intake area, is obtained by zig-zagging the filter, and the material is not homogeneous but is arranged in layers separated by wire gauze. The air passes through the filter at anything down to one two-hundredth of its initial velocity, so that the heavier dust particles fall before they reach the filtering media. Even the finest particles are not driven against the filter, but impinge lightly against it, so that the engine vibration is sufficient to shake most of them off, and the efficiency of the filter is maintained. The air pressure is not reduced by more than 0·15 in. water gauge, and the air flow regains its initial velocity as it enters the exit pipe of the filter. With the Protectomotor filter Vokes guarantees an efficiency of 99·9 per cent. for particles down to 0·00004 in. diameter.

In the strainer type of air filter the foreign matter is caught up by oil covering the surfaces of the baffles. A typical filter of this type is the Visco, which, in one of its simplest forms as fitted to small high-speed oil engines, consists of a perforated chromium-plated cylindrical casing having a perforated central tube, and with the annulus filled by Visco oiled rings. For larger installa-



Timken cannon type of inside roller bearing axlebox ; in this example, the A.E.C. shunting locomotive, the final drive is incorporated

Four-cylinder Westinghouse exhauster as used in the English Electric diesel trains for Ceylon



Layrub propeller shaft and flexible coupling

Visco type of air filter as fitted to small high speed engines

tions, the Visco standard filter comprises a number of baskets containing sinuous plates covered with oil. These plates divide the air stream into thin layers which in passing between the plates follow a sinuous course, and the dust particles are projected by centrifugal force on to the oil films. The baskets can be rotated by a wheel, so that they can be dropped one by one into an oil bath; as the dirtiest basket is dropped into the oil, the spare basket is raised automatically into the circuit.

Oil Reclamation

The desirability of installing a lubricating oil renovation plant depends upon the number of gallons of oil used in a given time, but few railways with more than the merest handful of railcars or locomotives can afford to neglect the economies which oil reclamation offers. Although there are about half-a-dozen methods of purification available, the equipment for railway purposes is usually either on the edge-filtration or centrifuging principles.

In filters or purifiers of the first type, such as the Streamline, the oil is forced against a pile of thin sheets of fibrous material placed like a pack of cards and held tightly together. Any solid matter is retained on the edges, where it may be cleaned off, and only the oil is forced through. It is claimed that the filter packs need renewal only about twice a year. In centrifugal plants, such as the Sharples and Hopkinson, the principle is to magnify the force of gravity to produce a rapid settling of the insoluble impurities, the accentuation of the gravitational force due to the rapid rotational movement varying from 8,000 to 20,000. This produces a compact unit which gives just as good results as an enormous settling tank, for water and impurities, being heavier than oil, are quickly thrown to the outside of the revolving liquid mass; and the clean oil tends to keep to the centre. Both the edge-filtration and centrifuging plants are generally operated on the bye-pass system, in which a portion of the oil in the engine circuit is passed continuously through the purifier, and is mixed automatically with the proportion of new oil needed for make-up.

Constitutents of one of the Vulcan-Sinclair fluid couplings to transmit 380 h.p. at 1,350 r.p.m., which are being supplied to the Belgian National Railways

Transmission Details

Despite the apparent simplicity of cardan shafts, the forces to which they are subjected and the angles through which they must operate have led to a good deal of trouble in one direction or another. A new shaft introduced last year, and used in the F and G trains of the Great Northern Railway of Ireland and in the L.M.S.R. six-engined trains, is the Layrub, in which there is no sliding splined assembly, no metal-to-metal contact, and no lubrication. Rubber is used for the resilient trunnion blocks, and gives smooth, quiet running without vibration or backlash. The Spicer type of shaft, with splined assemblies at the joints, now makes use of needle roller bearings at the flexible joints, and simplification has been further attained by the provision of a central lubricating point; the splines need lubrication attention every 3,500-4,000 miles, but the remainder of the assembly needs lubricant renewal only after 25,000 miles or so. A new type of Hardy-Spicer universal joint, the Uniflex, has been introduced as complementary to the above joint and shaft, and embodies rubber components.

Constant detail improvements are being made in the design and construction of fluid couplings of the Vulcan-Sinclair type, such as in the mounting of the coupling on the shafts, and in taking advantage of the momentary collapse of the fluid vortex to make an easy and quick gear change with mechanical transmission. A total of 350 Vulcan-Sinclair fluid couplings, capable of transmitting an aggregate of 46,175 h.p., were ordered during the year 1938, and the total number at work or on order at the end of that year was 1,194, with an aggregate capacity of 165,300 h.p.

A friction clutch disc new to railway work is the Don-Flex, which has given good service in Walker railcars in Ireland and South America. It comprises a flexible steel disc made up with two high-carbon steel laminations separated at the centre by a spacer washer. The washer increases the thickness of the disc at the inner diameter of the fabric by springing open the plates. Initial engagement takes place at this point, and as the pressure increases the disc gradually closes, and under full pressure is parallel in thickness.

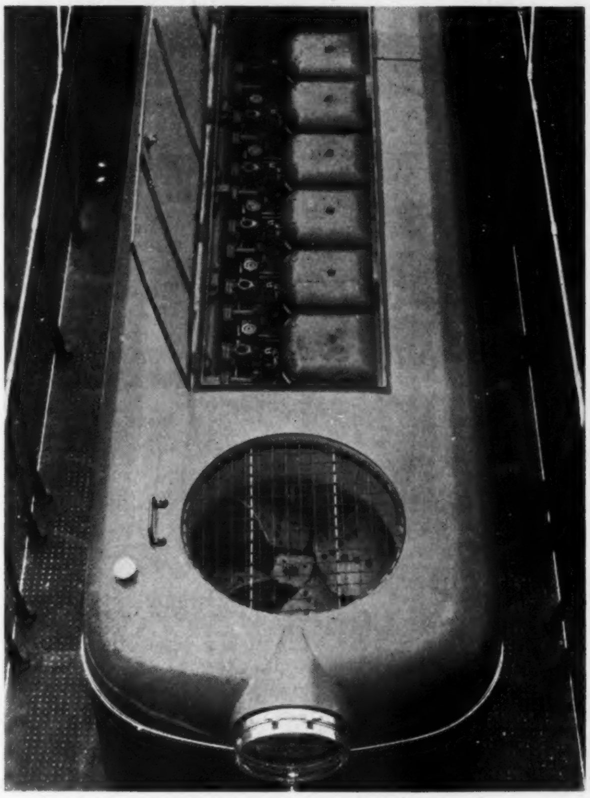
A REVIEW OF PROGRESS IN THE UNITED STATES

The year's deliveries and orders totalled eight train sets, a score of main-line locomotives, and over one hundred switching locomotives of from 90 to 120 tons in weight

THE beginning of a year devoted mainly to the construction of heavy main-line and shunting locomotives was marked by the introduction between Chicago and San Francisco of the second Union Pacific 17-car train, with an installed main and auxiliary engine capacity of 6,300 b.h.p. The tare weight of this train is 1,118 tons and the overall length 1,292 ft.; accommodation of the Pullman and sleeping type is provided for 222 extra-fare passengers.

In the dieselisation of long-distance passenger traffic the Atchison, Topeka & Santa Fe Railroad made most progress. In February a second Super-Chief extra-fare service was begun between Chicago and Los Angeles, with a 3,600 b.h.p. twin-unit oil-electric locomotive and a nine-car lightweight train. Both trains now in this service are of the lightweight type, mainly of stainless steel, and provide two trips a week in each direction on a 39¾-hr. schedule for the 2,229 miles. Later in the same month, the Santa Fe introduced two five-car lightweight trains, each hauled by an 1,800 b.h.p. oil-electric locomotive, and running between Chicago and Los Angeles to the same 39¾-hr. timing as the Super-Chief, although the accommodation, including a restaurant car, is simply for the ordinary fare passenger, of which 192 can be carried.

Thus there are four 56¼-m.p.h. diesel-hauled services a week in each direction between Chicago and California by the Santa Fe route, and in the State of California itself the Santa Fe has inaugurated the San Diegan, a six-car train which makes two double trips a day between Los Angeles and San Diego, behind a 1,800 b.h.p. oil-electric locomotive and the Golden Gates, two trains hauled by the same type of locomotive, making one round trip a day in each direction between San Francisco and Bakersfield. In April, 1938, the Santa Fe also introduced two similar trains running between Chicago, Kansas City and Wichita on a 58 m.p.h. schedule. The Santa Fe diesel stock now comprises two modern 3,600 b.h.p. and seven 1,800 b.h.p. oil-electric express passenger locomotives, all powered by the same type of 12-cylinder vee 900 b.h.p. Winton two-



An unusual view of one end of a 1,000-b.h.p. diesel locomotive for the Ford plant, showing one of the 500-b.h.p. Cooper-Bessemer engines and the electrically-driven radiator fan

The two 3,600-b.h.p. diesel-electric Super-Chief trains and the two 1,800-b.h.p. diesel-electric El Capitans, Santa Fe Railroad; between them is the Chief train, headed by a streamlined 4-6-4 steam locomotive

700-b.h.p. American switching locomotive with four main engines of the Caterpillar eight-cylinder vee type

stroke engine; and in addition, a large number of heavy 600 and 900 b.h.p. switchers. An order for no fewer than 30 new switchers of these two powers was placed just before the close of the year.

Two further locomotives of 3,600 b.h.p. were acquired by the Baltimore & Ohio Railroad in 1938, and they haul the Columbian and Royal Blue trains between New York and Washington; they are duplicates of the locomotives handling the Capitol Limited between Chicago and Washington. The B. & O. now has eight 3,600 or 1,800 b.h.p. main-line oil-electric locomotives, all powered by Winton two-stroke engines. The Seaboard Air Line ordered nine 1,800 b.h.p. Winton-engined passenger locomotives in the early summer, and the first batch of these was set to work at the beginning of December on the Orange Blossom Special, a winter-only train connecting Washington with the Southern resorts.

Another Zephyr

That pioneer high-speed diesel train line, the Chicago, Burlington & Quincy, has ordered a further stainless steel Zephyr train, to operate between Kansas City and St. Louis. The train is to have four cars, and the new Winton 12-cylinder 1,000 b.h.p. engine, giving an increase of 11 per cent. over the output of the existing 12-cylinder model, will form the power unit. Operating over six routes, the eight stainless steel trains now at work on the Burlington have covered an aggregate mileage of approximately 6,500,000, and thanks to the excellent system of maintenance the availability has averaged 95 per cent. since the original Zephyr went into traffic in November, 1934. The yearly mileage amounts to about 2,150,000, at average speeds of 51 to 66 m.p.h. The only remaining fixed train sets ordered in the U.S.A. during 1938 were four two-car units for the Southern Railroad, now being built by the St. Louis Car Company, and two similar formations for the Alabama Great Southern; in each case Fairbanks Morse engines are being installed in the leading car, and the remainder of the space in this vehicle is to be given over to baggage, parcels, and mails.

The great majority of the oil-electric switching locomotives delivered or ordered during the year were double-bogie types to Electro-Motive 600 and 900 b.h.p. and Alco 600 and 900 b.h.p. standard designs. The former incorporates the usual Winton eight-cylinder vertical or 12-cylinder vee two-stroke engine, and the second type the Alco six-cylinder vertical engine, giving 600 b.h.p. normally and Büchi-supercharged to give an increase of 50 per cent. when 900 b.h.p. is needed. These standard designs as a rule weigh 89 to 112 long tons. A handful of new models by other builders was put into traffic at various railway and industrial yards.

Deferred Payments

A hire-purchase system extending over a period of eight years has been adopted by the New York Central for the acquisition of 29 of these standard 600 b.h.p. locomotives, 20 by Electro-Motive and nine by Alco, the estimated weight of these particular units being 99 tons. The capital cost, spread over the eight years, is calculated at £375,000, or £12,900 per locomotive, including, presumably, extra interest charges. During the year the Chicago, Rock Island & Pacific Railroad contracted for the lease, in three separate batches of 11, 10, and 16, of 37 heavy switchers—29 of 600 b.h.p. and eight of 900 b.h.p., all of the Electro-Motive pattern. After the expiration of the seven-year leasing contract the railroad is to have the option of purchase; the gross rental of each 89-ton 600 b.h.p. unit will be about £14,000, and of each 112-ton 900 b.h.p. locomotive about £18,000. Other lines which purchased standard switching locomotives during the year were the Warrior River Terminal (one Alco 900 b.h.p.); the Reading (two Alco 900 b.h.p. and six Electro-Motive 600 b.h.p.); and the Grand Trunk Western, the U.S.A. line owned by the Canadian National (two 600 b.h.p. Electro-Motive). The last-named locomotives operate at Detroit, and can work into the various automobile factories, where the previous steam locomotives were not permitted.

Non-Standard Switchers

An unusual type of switcher developed during the year was that built by the Davenport-Besler Company. Powered by four 160 b.h.p. Caterpillar four-stroke engines, with a fifth, of 44 b.h.p., for auxiliaries, this locomotive has four normal nose-suspended traction motors giving a peak starting tractive effort of 63,000 lb. for an adhesion weight of 94 long tons, and thus differs from the Davenport-Besler double-bogie locomotive of a year or two back, which, in an endeavour to eliminate the weight-varying effects of nose-suspended motor torque reaction, was provided with two traction motors mounted on the underframe and driving the wheels through worms. Two 1,000 b.h.p. 118-ton double-bogie diesel-electric switchers ordered by the Ford Motor Company from the General Electric Company were put into traffic at the Rouge River plant. Powered by two 500 b.h.p. Cooper-Bessemer four-stroke engines, these locomotives can exert at the wheel rims a maximum tractive effort of 75,000 lb. up to a speed of 3 m.p.h., provided by four 220-h.p. force-ventilated motors driving the 40-in. wheels through 68: 15 spur gears.

The Texas Mexican Railway, a line with 162 miles of track, running from the Rio Grande to Corpus Christi, Texas, is purchasing seven 660 b.h.p. Baldwin diesel-electric locomotives with which it hopes to supplant the present stock of 16 steam locomotives in all passenger, freight, and switching operations. Six-cylinder Baldwin-De La Vergne four-stroke engines will be installed in these locomotives. Two Cummins 250 b.h.p. four-stroke engines were used in a rebuild of a d.c. electric locomotive into a 65-ton diesel-electric locomotive for the American Rolling Mill Company, which organisation has been a consistent user of a variety of diesel switchers during the last 10 or 11 years.

Diesel Railway Traction

Fuel Pumps

THERE will be few engineers who will not grant that the construction and operation of fuel injection pumps for small and medium-size high-speed diesel engines is a veritable *tour de force* of mechanical engineering. Consider, for example, the pumps fitted to a 12-cylinder railcar engine developing **300** b.h.p. at **1,500** r.p.m. on the four-stroke cycle. At a specific consumption of **200** gr. per b.h.p.hr., approximately **1** kg. (**2·204** lb.) of fuel a minute is used, and it must be metered and injected in no fewer than **9,000** equal parts in that time. In other words, each cylinder must be supplied **750** times a minute with **0·00011** of **2·204** lb.—**0·000245** lb.—of fuel at full load, the time of each ignition being limited to about **0·003** sec. By volume, this is equivalent to about **130** cu. mm. per charge, but the control of the pump must be flexible enough to permit of the delivery at idling of scarcely **10** per cent. of this charge about **250** times a minute. Yet this is a comparatively favourable example. There are other smaller engines running at **2,500** to **3,500** r.p.m. which require only **13** to **20** cu. mm. per charge, but the fuel pump must effect anything from **5,500** to **7,500** separate deliveries in **60** sec. at full speed, or at idling must meter and deliver individual quantities of only **2** or **3** cu. mm. Super-excellence of workmanship is required not only in the pump itself but in the injector nozzles also, for it will be appreciated that with such small quantities of fuel the slightest dribbling will represent quite an appreciable proportion of the normal full load.

Locomotives for Special Work

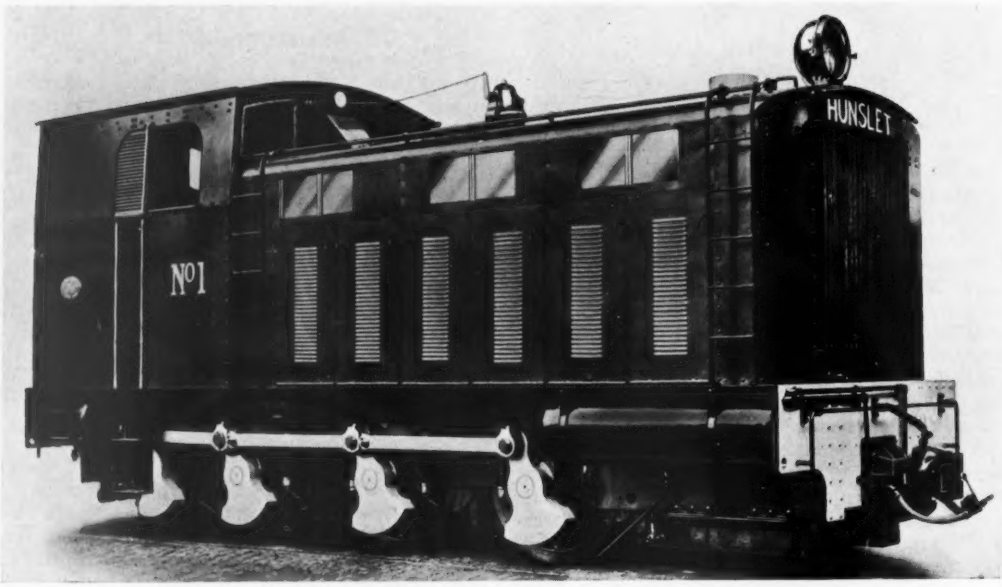
WITHIN the pages of this Supplement we describe three different diesel-mechanical locomotives, all of low power, all English-built, and all with unusual and progressive features—a thing we cannot recollect having been able to do in any other one issue since these Supplements began **80** months ago. There is a fairly large market for oil-engined locomotives within the range of **80** to **250** b.h.p. for shunting and short-distance transfer traffic, and although simplicity is the keynote as a rule, special requirements are by no means rare. Indeed, some makers almost pay their dividends on them, as the competition for small standard jobs is so keen that little profit is to be had from such orders. How well the variety of special conditions may be met is instanced by these three locomotives, and in two of them, at least, the particular features form distinct progressive steps in the field of diesel traction as a whole—first in the application of pressure-charging to cope with very high altitude, and second the simplification of controls to a point at which the steam locomotive is bettered without any sacrifice in operating performance. The fact that in neither case have lengthy service trials been completed is of little importance. The salient point is that theory has been advanced to practice, that actual units have been built, and have given satisfactory preliminary performance. Should either require any modification as a result of service experience, it is likely to be in detail only, and not commensurate, say, with serious alteration to superheater proportions following **30** years of superheating practice, or to radical alteration of wheel arrangement after a century of steam locomotive engineering. The one thing to be regretted about the English diesel locomotive-building industry, which technically is at least as good as any Continental or American standards, is that so few makers have the capacity to turn out large units, such as the **900** b.h.p. locomotives now required for Siam, or the much bigger locomotives which have reappeared on the diesel traction stage within the past two years or so, and intended both for high-speed and medium-speed service.

Siamese Enquiry

REWARDED by a tender of **£60,000** for a **1,000** b.h.p. diesel-electric locomotive in **1924**, the Siamese State Railways nevertheless continued to give this new form of traction careful attention, and in **1927** ordered from Switzerland two **180** b.h.p. diesel-mechanical locomotives for shunting and local train service. In **1931-32** a considerable advance was made by the delivery of six **1,000** b.h.p. express locomotives, one **1,600** b.h.p. main-line freight locomotive, six **450** b.h.p. mixed traffic units, and six **180** b.h.p. railcars. Apparently this stock has given such satisfaction as to lead to a desire for further diesel-electric units, and the specification recently issued by the Siamese State Railways, and obtainable from Messrs. Sandberg, the Consulting and Inspecting Engineers, calls for the supply of anything from one to nine locomotives in powers of **700** and **900** b.h.p. The larger locomotives are to have the **2-Do-2** wheel arrangement and the smaller units the **1-Co-1** layout. Conforming to general Siamese requirements, the maximum axle-load is limited to **11** metric tons and the maximum speed to **65** km.p.h. (**40** m.p.h.) Up a **1** in **50** grade the **900** b.h.p. locomotive has to haul a **420**-ton train at a maintained minimum speed of **15** km.p.h. The specification as a whole is extremely open and there are few items in it where the Siamese State Railways have laid down rigid requirements as the result of the six or seven years' operating experience with fair-sized diesel-electric units. However, one of the interesting technical points is that the engine cylinders must be capable of withdrawal either individually or in small blocks for repair or renewal. The fuel tank capacity for the **900** b.h.p. locomotive has to be sufficient for a journey of at least **2,500** km., and hauling a trailing load of **420** tons. This seems to indicate that use on the Singapore international trains is contemplated. The locomotives of **1927-1932** were European built, and one of the most interesting points about the present proposals will be whether the relatively small amount of experience of Japanese firms in the building of diesel locomotives will be offset by the low price which could be put forward by such makers as a result of the subsidisation of the Japanese export industry.

MIXED TRAFFIC LOCOMOTIVE FOR THE ANDES

39-ton British-built diesel-mechanical unit to operate over 1 in 14 adhesion grades at a height of 12,000 ft. is fitted with a Büchi pressure-charger to maintain the sea-level output, and has special starting and cooling equipment



General view of the new Guayaquil-La Paz Railway diesel locomotive

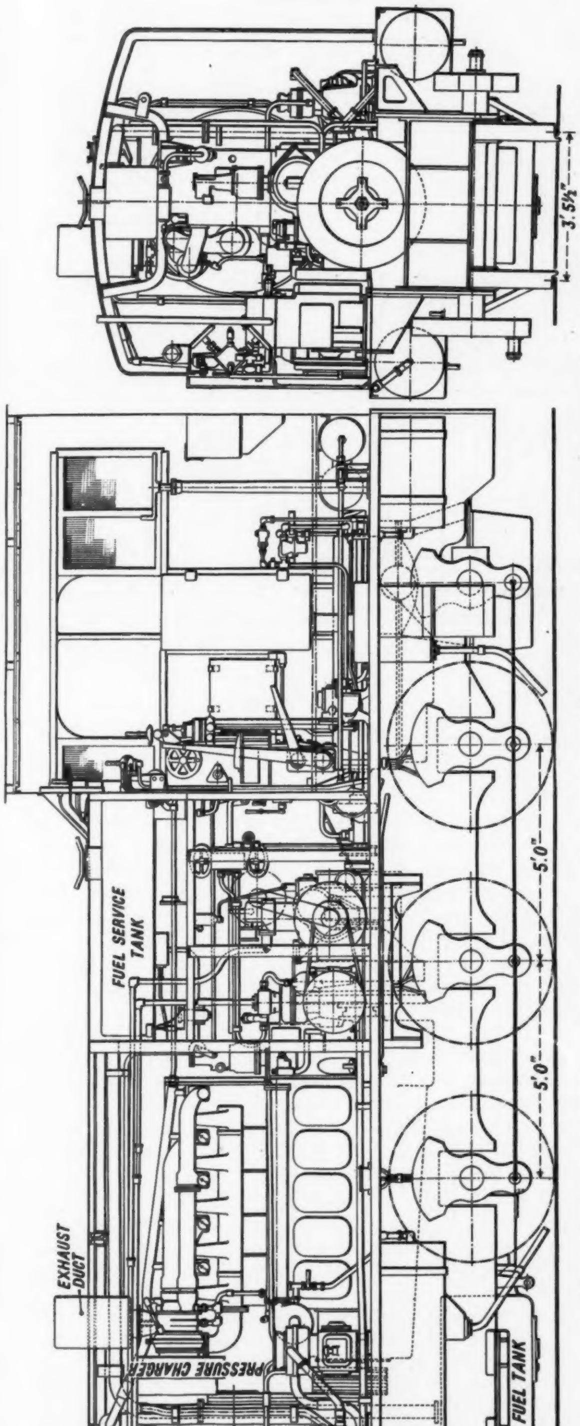
THE operation of diesel locomotives and railcars at high altitudes, particularly if in conjunction with severe grades, calls for quite a specialised design, not only as regards the oil engine and the maintenance of its power, but also with reference to certain of the auxiliaries and of the mechanical portion. The possibility of using economically diesel vehicles at altitudes such as those reached by railways in the Andes has followed the introduction of pressure-charging, for it is only by this means that the inherent loss of oil engine power with increasing height above sea-level can be compensated. Some early diesel cars set to work in Bolivia, for example, and running entirely above 10,000 ft., were provided with an engine having a nominal sea-level output of 380 b.h.p., although the requirements on site were equivalent only to about 220 b.h.p.

Most notable of recent vehicles intended for high-altitude operation is that shipped this month by the Hunslet Engine Co. Ltd., to the Guayaquil-La Paz Railway, a metre-gauge line owned by the Peruvian Corporation, and which lies mainly between 10,000 and 12,000 ft. above the level of the Pacific and has grades of 1 in 14. On the steepest section electric traction is in force, and rack and adhesion locomotives are used, but as further motive power became necessary it was decided to try diesel working without the use of the rack mechanism, and if the new type of power is successful there seems every possibility that it may supersede electric traction. The locomotive actually has been designed to operate satisfactorily up to 16,000 ft. above sea-level, which is a little above the maximum reached on any of the Peruvian Corporation's lines. A good test as to its performance at 14,000 ft. and thereabouts will be obtained when it is travelling from the Pacific Coast over the Antofagasta (Chili) & Bolivia Railway to take up its duties at La Paz, for the main line of this railway rises to over 15,000 ft. and runs for something like 100 miles at over the 10,000 ft. level.

Built to the inspection of Messrs. Livesey & Henderson, consulting engineers to the Peruvian Corporation, the new Hunslet locomotive is of the C (or 0-6-0) wheel arrangement, and has a four-speed mechanical transmission with the final drive to the 45-in. wheels through a jackshaft, flycranks, and rods. With the normal maximum engine speed of 900 r.p.m. the nominal track speeds are 5, 7½, 11, and 16 m.p.h., and the corresponding rail tractive efforts 15,500, 10,300, 7,000, and 4,800 lb. Related to the full loaded weight of 39 tons, the tractive effort on the bottom gear step gives a factor of adhesion of 5·6, or with the tanks empty, about 5·2. Based on the maximum engine torque at 16,000 ft. above sea-level, the maximum possible tractive effort is about 17,000 lb., but the torque falls somewhat at full engine speed, and at 900 r.p.m. is a maximum of 15,500 lb. at the highest altitudes. The maximum axle load is 13 tons, and the weight per foot run over couplers about 1·4 tons.

Mechanical Portion

The locomotive is built up on a heavy plate frame structure with a commodious cab at the back end, and a large bonnet, nearly the full width of the locomotive, covering the engine and auxiliaries. The arrangement of the bonnet is particularly noteworthy; side doors in the cab weatherboard enable the driver to go down each side within the bonnet to inspect the engine or other equipment, and further facilities are gained by having sliding inspection windows, supplied by Beckett, Laycock & Watkinson



General layout of 240 b.h.p. pressure-charged metre-gauge Hunslet diesel locomotive for operation in Bolivia

Limited, arranged down the side walls. The cab floor is at a high level, and the driving windows in the front weatherboard are above the bonnet level. Side louvres are fitted to the cab, and the roof is lined with Burgess insulation in order to eliminate drumming; insulation has not been applied to the board between the cab and engine room, as it is cut away a good deal for controls and pipes. A hot-water heater, fed from the engine cooling water system, is carried on each side of the cab. Centre couplers of the English Steel Corporation's make are fitted on the buffer beams.

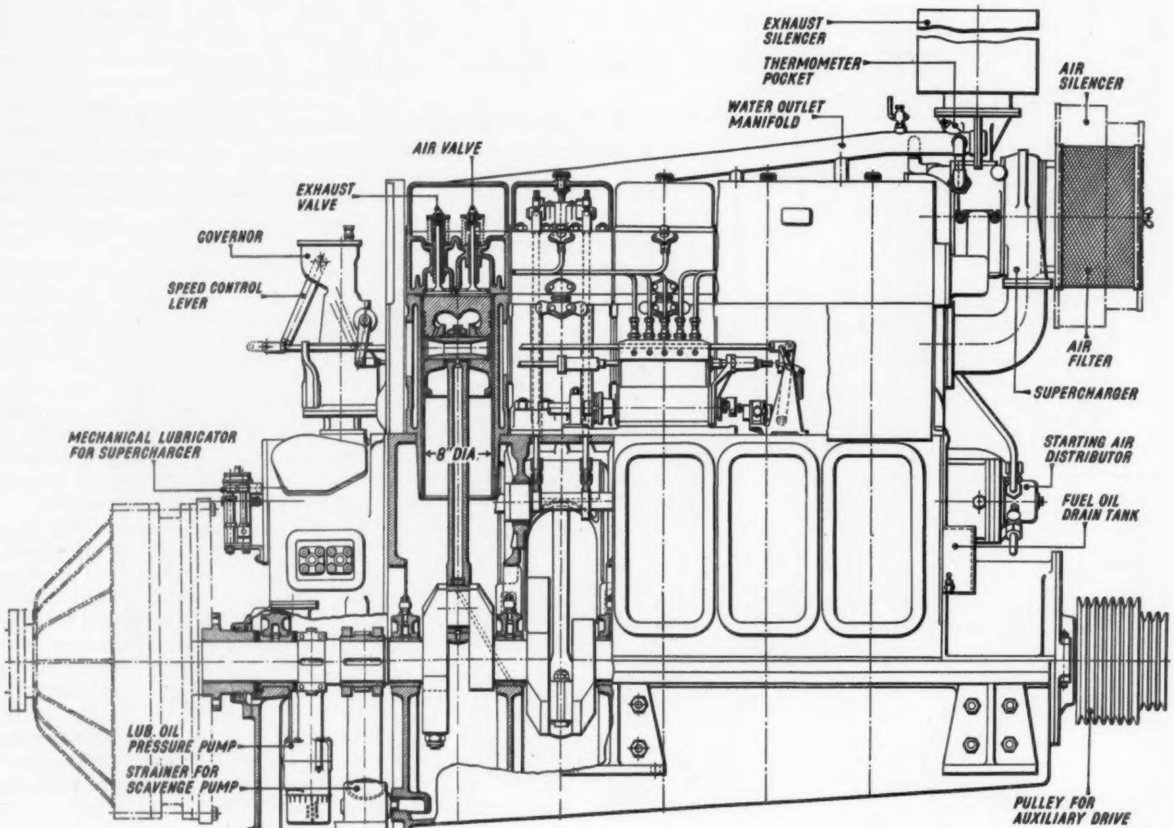
Stone's electrical equipment is provided, and includes a 750-watt Tonum dynamo, a 250-watt headlamp at each end, cab light, instrument light, engine room lamp, hand inspection lamp, a carbon-pile regulator, and the necessary switchgear, including dimming resistances. The batteries are of Stone's lead-acid type with a capacity of 200 amp.-hr. 24-volts. To comply with Bolivian conditions an American-type bell, made by John Taylor & Co. Ltd., of Loughborough, is carried on the engine room roof, and further warning is given by an air whistle, which has its own compressed air supply and reservoir.

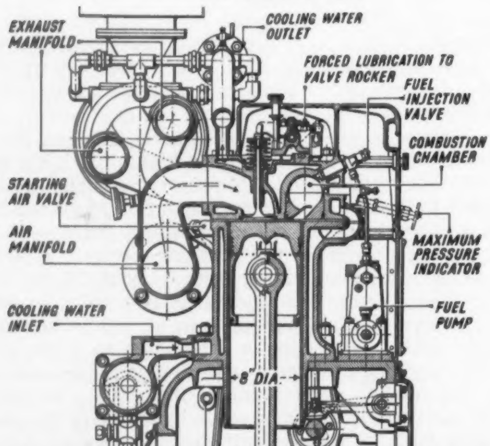
Comprehensive Westinghouse braking equipment is incorporated because of the severe gradients; it comprises a straight air brake, with self-lapping valve, on the locomotive; straight air brake for the train only; and an automatic brake for the locomotive and train. Controls for the straight air brake on the locomotive are provided at each side of the cab, but the driver's valves for the other two systems are located on the right-hand side only. Brake air is supplied at a pressure of 100 lb. per sq. in. by duplicate two-cylinder water-cooled Reavell compressors of 50 cu. ft. per min. capacity each, and driven from the main engine by Thrapston Vulco endless vee belts. A hand brake of the usual type is fitted also.

Engine and Auxiliaries

Traction power is provided by a Mirrlees 5UD four-stroke engine with five cylinders 8 in. bore by 12 in. stroke and normally developing 330 b.h.p. at 900 r.p.m. It is equipped with a Büchi exhaust gas turbo pressure-charger nominally capable of increasing the engine output by 50 per cent., that is, to 495 b.h.p. at sea-level. But as the locomotive is to work consistently at a high altitude the engine has been de-rated by adjustment of the fuel injection to give 220 to 240 b.h.p., which figures can be maintained at 900 r.p.m. up to 14,000 ft., thanks to the pressure-charger. Under these conditions the charging pressure is 4·45 lb. per sq. in. and the blower speed about 23,000 r.p.m. The cylinder compression pressure is nominally 530 lb. per sq. in., the maximum pressure is 760 to 800 lb. per sq. in., and the injection nozzle is set to 1,800 lb. per sq. in. The engine idles at 540 to 550 r.p.m. and under load is limited to a maximum of 900 r.p.m., but in view of the mechanical transmission it is necessary to vary the speed of the oil engine to suit the haulage conditions; the engine therefore is fitted with a variable-speed governor at the end opposite to the pressure-charger, and by means of distant control from the cab, the engine speed can be varied from 280 to 900 r.p.m. under load. C.A.V.-Bosch fuel injection equipment is used.

The engine bedplate is cast separately from the column and carries all the main bearings. It is of cast iron and is substantially ribbed to give rigidity without unduly increasing the weight. The column is of the box type, of very deep section to give stiffness, and is provided with large aluminium inspection doors both back and front. Each cylinder is a separate iron casting and is provided with ample cooling water spaces; two large doors are fitted to the water spaces for cleaning purposes. After rough machining and before final machining the cylinder cast-



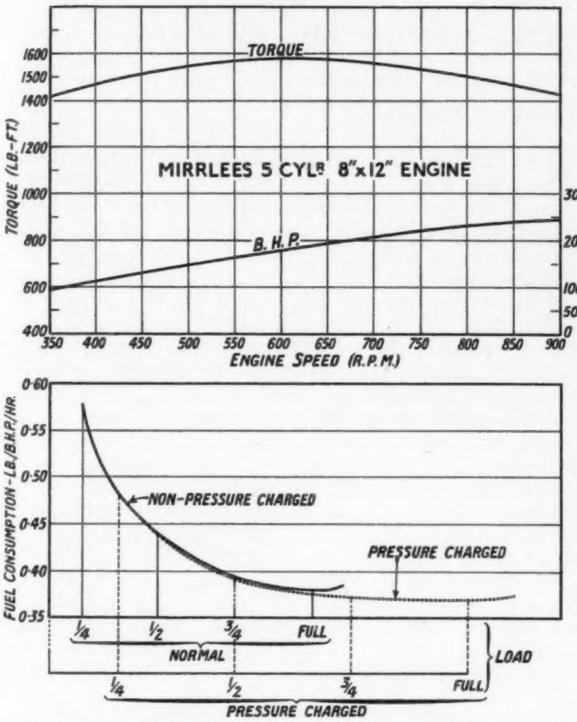


Longitudinal and cross-sections of Mirrlees-Ricardo five-cylinder engine

ings are annealed to release any internal stresses. The cylinders are fitted with dry liners, the bores of which are honed after all other machining has been completed. Ricardo Comet heads are embodied; the heads are of cast iron, but the lower portion of the combustion chamber, including the hot throat, is of heat-resisting steel.

The air inlet at the end of the engine is fitted with a Burgess combined silencer and filter, as the engine is to operate in a dusty atmosphere. Other auxiliaries on the engine are the centrifugal cooling water pump, a dynamo, and the radiator fan, all of which are driven direct. The main fuel tank is located between the locomotive frames on the front end and has a capacity of 235 gal.; a fuel transfer pump, driven from the free end of the fuel pump on the main engine, pumps the fuel through a non-return valve to a 65-gal. service tank within the bonnet and just in front of the cab. An Auto-Klean filter is inserted in the fuel line. Exhaust temperature thermometers made by the British Rototherm Co. Ltd. are fitted to the cylinders as a check on the engine and pressure-charger performance.

The greatest care has been taken to ensure efficient cooling. Although air temperatures round La Paz are frequently very low, they vary over a wide range. The density of the air is so greatly reduced at these high altitudes that the capacity for carrying away heat is reduced proportionately, making a great increase in radiator size imperative. Water also has a much lower boiling point, so that to maintain the correct water temperature a slight pressure is allowed, thus avoiding premature boiling. The radiator frame is built up of heavy rolled steel channels, while welded steel top and bottom tanks are joined by twelve quickly detachable Serck cooling elements, two of which are devoted to oil cooling.



Power, torque, and fuel consumption curves of normal and pressure-charged Mirrlees-Ricardo engines

Mechanically-operated shutters are fitted over the radiator bank in order to vary the cooling effect as required. A battery of four thermostats is inserted in the cooling water system.

Starting Equipment

Although only 17 deg. south of the equator, the La Paz district experiences low night temperatures due to the altitude, and, combined with the rarity of the atmosphere, made essential a careful consideration of the main engine starting process. In order that there should be no question of inability to start even under the worst conditions, two entirely independent sets of starting equipment have been provided.

As the main set of equipment, a diesel-compressor set is carried on the left-hand side of the locomotive. It comprises an Ailsa-Craig four-stroke engine normally developing 25 b.h.p. at 1,500 r.p.m. at sea-level, but permanently de-rated to give 12½ b.h.p. at the working altitude, and a two-stage Reavell compressor which is driven by Thrapston Vulco vee belts. The engine itself is electrically started, but has a further hand starter, and the set is capable of charging two large air reservoirs to a pressure of 500 lb. per sq. in. Under normal English conditions the main engine starts very easily; when moderately warm a pressure of 250 to 300 lb. per sq. in. is adequate, and if the full 500 lb. is available the reduction in pressure in the reservoirs is only 5 to 7 lb. per sq. in.

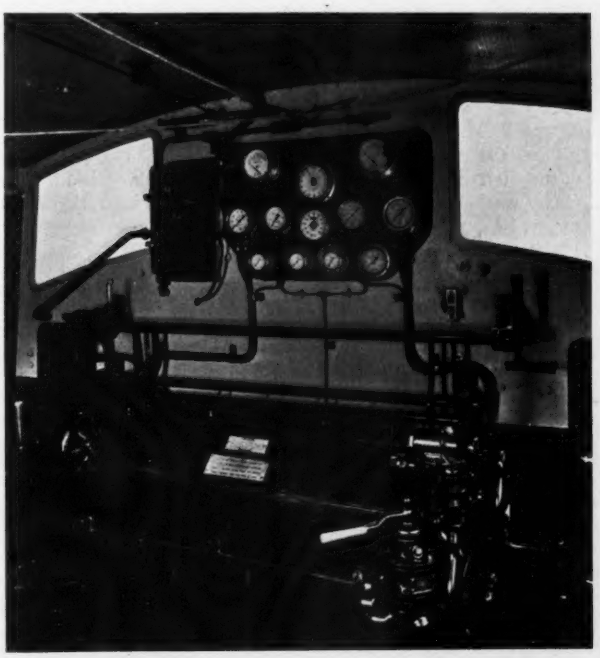
The emergency starting set comprises a Ford V8 petrol engine and a Bendix gear meshing with a ring on the flywheel, and is mounted on the right-hand side of the locomotive. It has both electric and hand starting equipment, the former being of C.A.V.-Bosch manufacture. Being capable of a maximum output of 95 b.h.p. at 4,000 r.p.m., it has not the slightest difficulty in starting the main engine, and can motor round the main unit for any length of time. The gearbox, clutch, and Bendix operating gear were designed and made at the Hunslet works, and the complete set, including a small petrol tank, can be lifted out on one bracket.

Transmission

Behind the engine the transmission consists of, in sequence, a Vulcan-Sinclair fluid coupling, an internal-expanding brake, the Hunslet auxiliary gear-change clutch, a short cardan shaft and Hardy-Spicer flexible coupling, and a four-speed Hunslet constant-mesh gearbox with self-selecting mechanism and patent power change-gear control. The auxiliary friction clutch, with Ferodo linings, is inserted in order to supplement the effect of the fluid coupling, and in its turn this eliminates wear from the clutch. The duties of the clutch are light, and the size actually fitted to this locomotive is that normally used as a main clutch for 100 b.h.p. locomotives. The transmission brake simply holds the shaft while the clutch engages and prevents any jar in taking up the load while the locomotive is at rest.

As in normal Hunslet practice, a single handwheel in the cab controls in correct sequence the throttle and the gear changes, the consecutive actions being effected by a series of cam-operated pneumatic valves which deliver air at a pressure of 50 lb. per sq. in., and taken from the main air supply through a reducing valve to the cylinders operating the selector, the gears, the clutch, and the engine throttle. This and the other locomotive controls are duplicated, one set being provided at each side of the cab. As the gear-changing is effected automatically, though under the driver's control, a gear-step indicator is fitted on the gauge panel to show the driver in which gear step he is operating.

The four-speed Hunslet gearbox is located below the cab floor. The box itself is built up of welded steel plate, and is split on each shaft line in order to facilitate inspection and dismantling. The right-angle drive is formed of spiral bevels, but the remaining change-speed and final reduction gears are of the helical type. All the gearbox shafts run in Ransome & Marles ball and roller bearings and the jackshaft is carried on heavy SKF roller bearings. The gearbox complete weighs 6 tons.



Interior of cab of Hunslet locomotive, showing A.T. speedometer surrounded by various air, oil and fuel gauges

THE L.M.S.R. THREE-CAR DIESEL-HYDRAULIC TRAIN

A discussion on its design and operation at the Institution of Locomotive Engineers

THE presentation of a paper entitled " A Diesel Train With Multiple Axle Drives," by Mr. T. Hornbuckle and Dr. H. F. Haworth, before the Institution of Locomotive Engineers, on January 25, evoked a long and interesting discussion. The paper itself was taken up mainly with a description of the train and need not be abstracted here, as a complete description was given in the issue of this Supplement for April 15, 1938. However, the authors gave an account of the failures which had been encountered during the trial period extending from January 25 to September 5, 1938, but gave no indication of its detailed behaviour in regular service between September and the end of the year.

The paper was largely taken as having been read, but Mr. Hornbuckle gave a brief description of some of the alterations which had been found necessary after service experience, such as giving additional clearance between certain transmission members and the underframe, provision of a second brake compressor, improved cooling arrangements, and the fitting of protective wire over the driver's windows. Mr. Lucy, of Leyland Motors Limited, who was deputising for Dr. Haworth, gave additional particulars of the power and transmission equipment. The dry weight of an engine was 1,314 lb., equivalent to about 10·7 lb. per b.h.p. The calculated tractive effort of the train was 17,500 lb. at the wheel rims at starting, 6,600 lb. at 30 m.p.h., and 3,300 lb. at 75 m.p.h. Measured accelerations on straight level track were from rest to 7·6 m.p.h. in 4·4 sec; to 16·6 m.p.h. in 11·4 sec.; to 22·7 m.p.h. in 18·4 sec.; to 30·3 m.p.h. in 29 sec.; to 37·9 m.p.h. in 43·4 sec.; to 44 m.p.h. in 60 sec.; to 60·5 m.p.h. in 125 sec.; and to 75·8 m.p.h. in 185 sec.

Experience with Cooling Arrangements

The discussion was opened by Mr. LeClair, of the Westinghouse Brake & Signal Co. Ltd., who expressed a fervent hope that the experience of the L.M.S.R. would lead that company to build further diesel trains in the near future. Mr. L. H. Short, of the English Electric Co. Ltd., drew attention to the large potential mileage of the L.M.S.R. train. Working on the basis of figures given, *viz.*, 22,000 miles in 49 working days, this was equivalent to an annual mileage of 135,000. Although there were certain advantages in multi-engined trains, it might be possible that maintenance costs would be unduly high; experience with pure electric traction had shown that the maintenance cost was roughly proportional to the number of motors and not to their size. Mr. F. C. Johansen, of the Research Department of the L.M.S.R., gave some detailed particulars of airflow measurements and alterations which had been carried out to the cooling system generally. With the train in its original condition the projecting area of the scoops was 1·15 sq. ft., but once past the scoop the air passed through a transverse rectangular duct with an area of 5·4 sq. ft. and issued in a downstream direction on the opposite side of the car. There had been difficulty in obtaining adequate airflow, and the velocity along the transverse duct was only 6 ft. per sec., equivalent to a water head of only 0·01 of an inch. The original flow of 2,150 cu. ft. per min. through the radiator was not enough and had to be improved by the insertion of additional vanes in the scoops. However. the layout was improved to give a through airflow of 3,000 cu. ft. per min. at a track speed of 60 m.p.h. In still air the airflow was found to be closely proportional to the track speed.

Mr. J. F. Alcock, of the Hunslet Engine Co. Ltd., asked for further detailed information about the control of the engine throttles and the sequence of operation, and particularly some elaboration of the statement in the paper that experience had shown it to be preferable to keep the throttle fully open. Mr. C. F. Cleaver, of the A.E.C., drew attention to the loading of the bolster springs on the articulation bogie. On a 3½-chain curve rough calculations showed that about 60 per cent. of the supported weight must be taken up by the outer springs. Some cooling trouble was experienced with the early A.E.C. cars on the G.W.R., but when steps had been taken to get rid of the air suspended in the water by the provision of a small header tank under one of the seats, the trouble had been largely solved. He did not attach much importance to all the engines in a multi-engined train giving exactly the same output. He suggested that some of the trouble the L.M.S.R. had experienced as a result of the driving windows being damaged in collisions with birds might be avoided if the windows sloped back; no trouble had been experienced in this direction on the G.W.R.

Effect of Mileage on Repairs

Mr. W. C. Williams, of Beyer, Peacock & Co. Ltd., said that one naturally expected diesels to give a far bigger mileage than steam trains, but he desired to know what total mileage between general repairs was expected with the L.M.S.R. train, and what was the maintenance and repair cost visualised. Mr. W. S. Graff-Baker, of the L.P.T.B., said that some time ago London Transport had considered the building of a diesel-electric locomotive for works service, and which would be powered by a number of the standard bus engines, but a multi-engined locomotive had not appealed to them. In various branches of engineering, some trouble had been occasioned in making satisfactory welds with high-tensile steel, and he would like to know if the L.M.S.R. engineers had met with this, and if so, had they been able to get over it. The question of maintenance of engines and other equipment was largely bound up with the number of starts and stops per mile. With stops about half-a-mile apart the L.P.T.B. electric trains ran 70,000 miles a year each, but on the outer sections, where stops were up to three miles apart, the yearly mileage was enormously increased. Bus engine service, simply because of the frequent stops and frequent changes of load, was extremely arduous, and it was this which governed almost entirely the life of the engine.

Mr. E. S. Cox, of the L.M.S.R., desired further information as to the use to which such sets as the three-car train could be put. The train seemed to have great potentialities, although it could hardly lend itself to extension into, say, a nine-car main-line train, which on the same basis would have to be powered by 18 engines. Mr. C. M. Beckett remarked that although the introduction of hydraulic transmisson was supposed to result in great simplicity compared with electric transmission, the paper showed that a large amount of electric control apparatus was necessary, composed almost entirely of small parts which were quite the worst from the maintenance point of view. Mr. Jenkins asked for further information about repairs to the engines, particularly as to whether the engines could be changed simply, or if ordinary maintenance work could be carried out without trouble. Mr. A. K. Bruce

stressed the importance of the train weight, particularly in regard to stresses on the transmission components when accelerating. He expressed surprise that fan-cooled radiators had not been incorporated, particularly as all the cooling equipment was located below the floor. He mentioned a temperature difference of 10° C. between water inlet and water outlet as being common in fast railcars on the Continent.

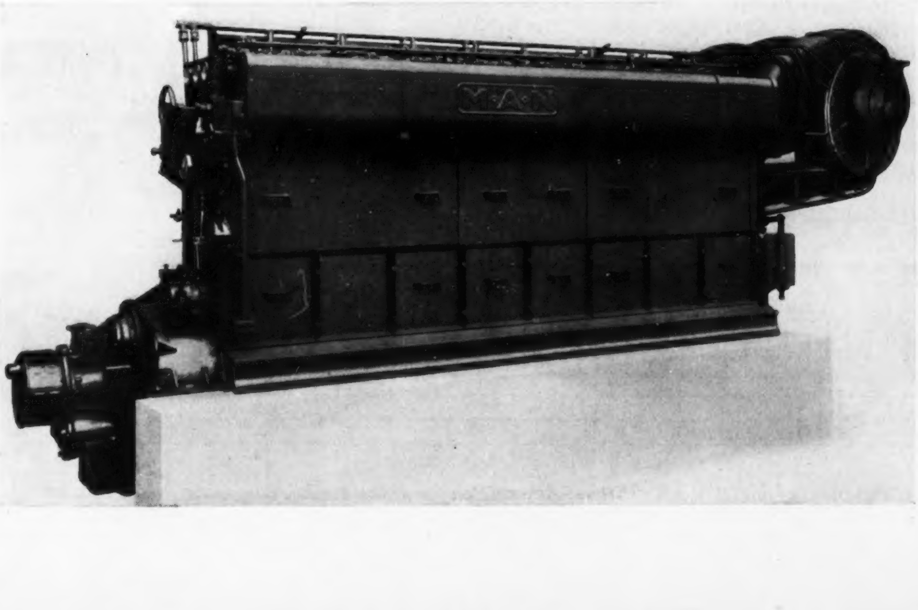
Authors' Replies

Mr. T. Hornbuckle, in his reply, stated that he expected the servicing of the power equipment would be determined mainly by the mechanical portion. If the tyres needed re-turning after, say, 80,000 to 100,000 miles, the power equipment would then be given its overhaul. He agreed with various speakers that too much emphasis appeared to have been made earlier on the desirability of each engine doing exactly the same amount of work. The brakes had originally given a greater rate of retardation than had been expected, and he believed that this was due to the extremely simple apparatus between the cylinder and the blocks which eliminated the serious inefficiency of the normal type of brake rigging. In reply to Mr. Graff-Baker, he believed that the problems relating to the welding of high-tensile steel had been overcome. In reply to Mr. Cleaver's remarks about weight on the bolster springs round the minimum curve, Mr. Hornbuckle emphasised that 3½ chains was almost an emergency figure and the train would go round it dead slow; the normal minimum was 5 chains. The train had not been in regular service long enough to give detailed repair figures, but it was not expected that the repair costs would be a serious item. As regards the potentialities of such trains and other diesel units, he could not help feeling that the numerous two-coach 60-ton trains hauled by 110-ton steam locomotives which could be found all over the country were hardly the thing, and they might be supplanted easily by diesel stock. The engines of the L.M.S.R. train were fairly accessible, at least if they were placed over the pit; it was then possible to drop the complete engine and replace it by another, and cylinder heads and pistons could be changed through the car floor. Mr. Lucy, in his reply dealing with the power equipment, also referred to experience having shown that it was not necessary to have all engines giving exactly the same output. The means that had been taken originally were the careful calibration of the fuel pumps and the marking on a protractor plate of the various positions available in each engine, such as full load and three-quarter load. The temperature difference mentioned by Mr. Bruce applied also to the engines installed in the L.M.S.R. train. The throttle control was carried out through self-lapping valves which regulated six small pistons working against calibrated springs. Certain minor troubles had been occasioned at first by the sticking of various levers, but in general the operation had been quite satisfactory.

Leipzig Trade Fair Exhibits

THERE is usually a fairly strong oil engine section at the annual Leipzig trade fair, and at this year's show are several examples of railway-type engines. In hall 21 the Deutsche Werke Kiel is showing three types of engine, one developing 240 b.h.p. at 500 r.p.m., suitable for medium or small locomotives where light weight is not a consideration, and one, giving 120 b.h.p. at 1,300 r.p.m., suitable for small railcars or tractors; the third is a 345 b.h.p. producer-gas engine running at 375 r.p.m.

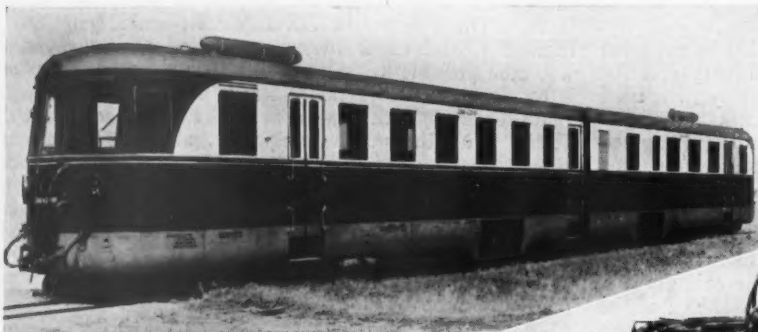
Among the M.A.N. exhibits is one of the 12-cylinder 275 b.h.p. horizontal railcar oil engines with a top speed of 1,500 r.p.m., and, probably most interesting of all the railway diesel exhibits, an eight-cylinder Büchi-pressure-charged vertical four-stroke engine with a nominal maximum output of 1,400 b.h.p. at 700 r.p.m., which output can be maintained up to a height of 1,650 ft. above sea-level at a temperature of 20° C. As exhibited, the engine is intended for locomotive applications, and the crankcase and cylinder block are of a special cast iron, with chrome-nickel steel cross pieces carrying the main bearings. The cylinders are 300 mm. bore by 380 mm. stroke, and at the maximum governed output the m.e.p. is 120 lb. per sq. in. and the piston speed 1,750 ft. per min. The cast-iron cylinder heads each contain two inlet and two exhaust valves, operated from a camshaft gear-driven by the main crankshaft. Light-metal pistons are used and are secured to high-tensile alloy steel connecting rods. Pressure lubrication is applied to the main bearings, big ends, gudgeon pins, and camshaft bearings, and two pumps maintain the circuit. Either compressed air or electric starting can be incorporated.



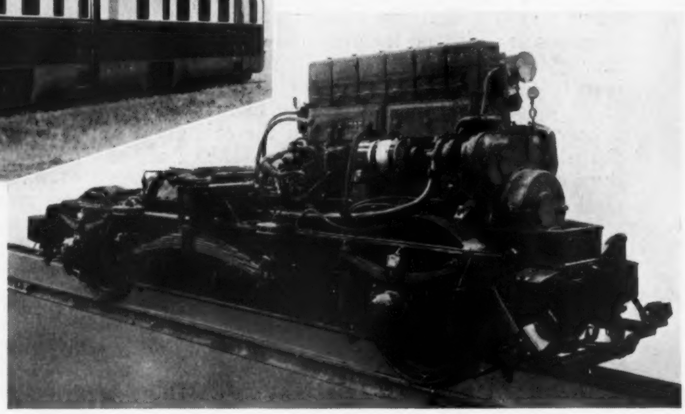
1,400-b.h.p. M.A.N. oil engine for main-line locomotive applications. A Büchi exhaust-gas pressure-charger is incorporated. A similar engine but with welded steel framing and sundry modifications is used in the four-car diesel-electric express train on the Reichsbahn

Diesel-Mechanical Trains for Interurban Service in Greece

Twin-car sets for solo or multiple operation over 1 in 40 grades with 260-ft. curves



***Left:* General view of 420 b.h.p. double-engined semi-streamlined articulated set with welded all-steel body**

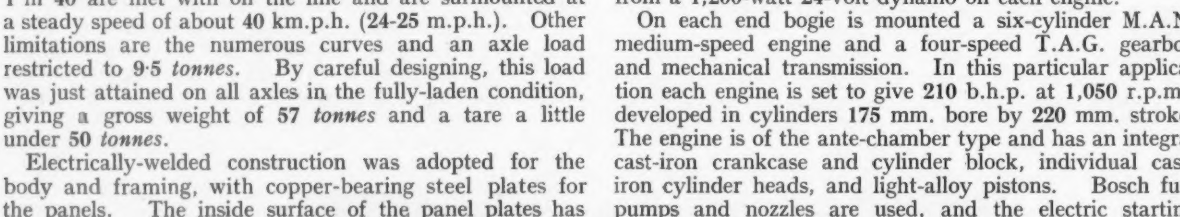


***Right:* Metre-gauge bogie carrying M.A.N. 210 b.h.p. engine and T.A.G. gearbox. The engine is mounted on a subframe with three-point suspension, and the gearbox unit has four-point suspension. The wheelbase is 11 ft. 6 in.**

In order to provide accelerated schedules and greater comfort on important point-to-point services, the Piræus-Athens-Peloponnesus Railway has put into traffic eight twin-car articulated diesel-mechanical trains. Built by the Linke-Hoffmann-Werke, these trains are now operating on the metre-gauge Piræus—Athens—Kalamata and Piræus—Athens—Kyparissia sections, where they are allowed a top speed of 65 km.p.h. (40 m.p.h.). Grades of 1 in 40 are met with on the line and are surmounted at a steady speed of about 40 km.p.h. (24-25 m.p.h.). Other limitations are the numerous curves and an axle load restricted to 9·5 *tonnes*. By careful designing, this load was just attained on all axles in the fully-laden condition, giving a gross weight of 57 *tonnes* and a tare a little under 50 *tonnes*.

Electrically-welded construction was adopted for the body and framing, with copper-bearing steel plates for the panels. The inside surface of the panel plates has an insulation lining of Agu composition. All the first class seats have individual arm rests and are upholstered in plush; the third class seats are arranged two and two on each side of the central gangway, and are upholstered in imitation leather. A buffet-bar is incorporated to give a light refreshment service. Heating of the train interior in winter is effected by circulation of the engine cooling water, the system of each car being independent. Welded steel construction has been used for the bogies, which have 830 mm. (32¾ in.) wheels, and axles carried in SKF roller bearings. Braking is on the Knorr automatic compressed air system, and on each underframe is carried a 12-in. cylinder which operates clasp blocks on each wheel of the corresponding driving bogie and on two wheels of the articulation bogie. Electric lighting is provided from a 1,200-watt 24-volt dynamo on each engine.

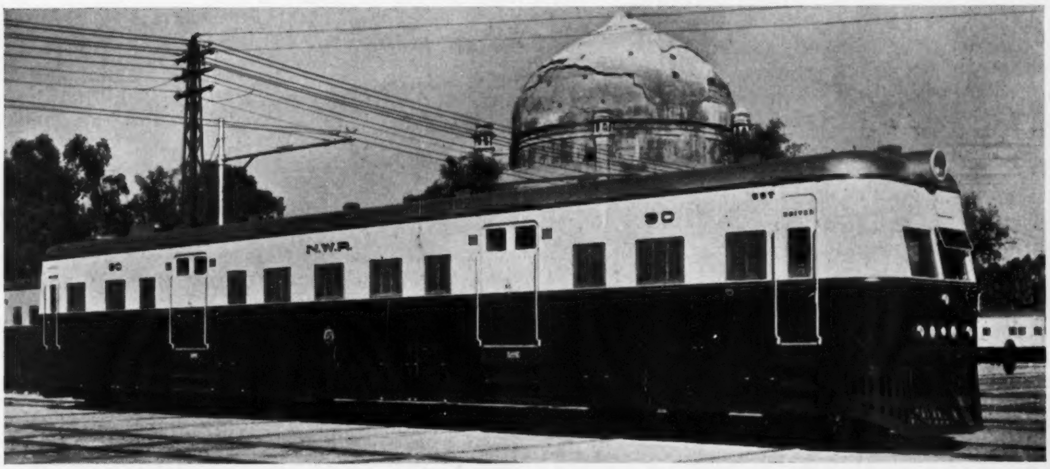
On each end bogie is mounted a six-cylinder M.A.N. medium-speed engine and a four-speed T.A.G. gearbox and mechanical transmission. In this particular application each engine is set to give 210 b.h.p. at 1,050 r.p.m., developed in cylinders 175 mm. bore by 220 mm. stroke. The engine is of the ante-chamber type and has an integral cast-iron crankcase and cylinder block, individual cast-iron cylinder heads, and light-alloy pistons. Bosch fuel pumps and nozzles are used, and the electric starting motor is of this make also. Cooling water and lubricating oil radiators are slung beneath the car floor and each set is provided with a fan driven from the mechanical transmission. The cooling arrangements are sufficient to counteract the summer air temperatures of 50° C. In each engine room are located two fuel tanks with a combined capacity of 700 litres (154 gal.).



Floor plan of buffet train, Piræus-Athens-Peloponnesus Railway

AN INDIAN EXTENSION OF DIESEL TRACTION

Broad-gauge vehicles for native traffic in Punjab



One of the 250-b.h.p. Ganz cars newly arrived at Moghalpura works, North Western Railway

THE eleven Ganz railcars ordered a little over a year ago for service on the broad-gauge lines of the North Western Railway of India have all been delivered and some of them are now in traffic, centred on Jullunder and scheduled to make individual daily mileages up to 475 miles. These cars were shipped to India in the Belray, one of Christen Smith's special vessels for the transportation of railway stock. Only third class passengers are carried, and a total of 101 seats have been provided on a tare weight of about 31 tons. Fully laden with passengers, luggage, and supplies the weight is about 41 tons, and the maximum axle load 13 tons. A top speed of 55 m.p.h. can be maintained on straight level track and 37 m.p.h. up a grade of 1 in 100. Fuel sufficient for a run of approximately 600 miles is carried, and there is a driving position at each end in order to obviate turning at the end of a run.

In accordance with standard Ganz practice, welded construction, using medium-tensile chrome steel, has been adopted for the body framing and for the bogie frame structure. The body framing and underframing are formed as an integral girder. The bogies are of the usual Ganz non-bolster type with the suspension comprised entirely of nests of helical steel springs supplemented by rubber cushioning blocks, and with a frame structure rigid enough to resist vertical or lateral deformation despite the comparatively long wheelbase.

On one of the two bogies is mounted a Ganz-Jendrassik six-cylinder engine driving a five-speed gearbox. The engine has cylinders 170 mm. bore by 240 mm. stroke (6·7 in. by 9·5 in.), and in these particular applications is set to give a maximum output of 250 b.h.p. at a speed of 1,250 r.p.m. The weight is about 20 lb. per b.h.p., the piston speed 1,800 ft. per min., and the m.e.p. 85 lb. per sq. in. A cast light alloy is used for the crankcase, above which are three cast-iron cylinder blocks. Ganz fuel injection pumps are fitted. Behind the driving bogie pivot, and connected by a short cardan shaft with the Hardy type of flexible coupling, is the five-speed Ganz gearbox, preceded by a friction main clutch with Ferodo-lined steel discs and by a spur-gear reverse. The control of the change-speed gears, reversing gear, and main clutch is on the electro-pneumatic principle. The radiators and other auxiliaries are carried on a subframe below the floor.

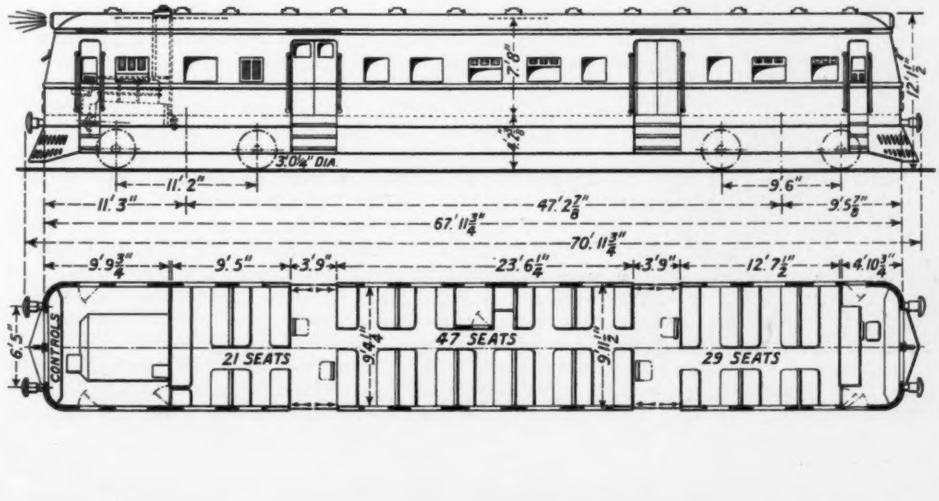


Diagram of one of the 100-seater 31-ton diesel-mechanical cars for 5-ft. 6-in. gauge lines. The engine and transmission are mounted on one bogie and the other bogie is of the non-driving type

A NEW STEELWORKS DIESEL LOCOMOTIVE

Special equipment incorporated in mechanical-drive unit handling heavy ore transfer traffic in South Wales

30-*ton Fowler industrial shunting locomotive*

AMONG the most interesting of the diesel locomotives recently set to work in special traffic is one built by John Fowler & Co. (Leeds) Ltd. for Richard Thomas & Co. Ltd., and now in use at the steelworks section of the owner's new Ebbw Vale plant. It is used to haul an 80-ton dump car, and is fitted with Westinghouse compressed air equipment for operating the door opening and closing mechanism on this transfer car when the discharge of ore is to take place. The ore transfer car itself was built by Ashmore, Benson, Pease & Co. Ltd., of Stockton-upon-Tees.

The Locomotive

Of the C, or 0-6-0, wheel arrangement, the locomotive runs on standard-gauge tracks, and has 39-in. wheels spread over a base of 8 ft. 6 in., which is short enough for the locomotive to negotiate curves of 120 ft. radius. The working order weight is 31 tons, giving a factor of adhesion of 5·3 against the maximum tractive effort of 13,000 lb. The mechanical portion is built up on a heavy steel plate frame structure having very rigid cross-bracing, and comprises a central cab with dual control for the throttle, clutch, and air brakes, and flanked at each end by a large bonnet, one of which houses the main engine and the other certain auxiliary equipment. The cab is totally enclosed and has sliding doors and hinged windows; a heater is installed for use in cold weather. In general, the detailed construction of the mechanical portion follows the lines of heavy industrial steam shunting locomotives, and embodies cast steel axleboxes with gunmetal bushes, cast steel wheels, standard buffing and drawgear, and a hand screw brake. Other equipment includes electric headlamps and red marker lamps at each end; cab and hand inspection lamps; at each end a downward-tilting electric lamp arranged to facilitate coupling and uncoupling at night; a compressed air warning horn; and air sanding gear to the end wheels. Despite the application of pneumatic sanding, care has been taken to get a free and straight drop from the large sandboxes to the rails, as may be seen in the diagram of the locomotive reproduced on the next page. Overhung laminated springs are used, and an unusual feature is that the springs down each side are equalised, giving the locomotive a two-point suspension system. Clear access to the engine and certain of the auxiliaries is gained through the large double hinged doors, which occupy most of the space on each side of the engine bonnet. Wide footsteps are fitted below the cab doors, and single steps against each buffer beam.

Westinghouse air brake equipment is incorporated, and comprises a straight air brake controlled by means of an improved form of self-lapping driver's brake valve, and an emergency brake providing automatic application on both the locomotive and the dump car should there be any loss of air from the emergency pipe through a breakaway or any other cause. In addition, Westinghouse door control is embodied for operation of the dump car doors by admission or exhaust of air to the two pipe lines connected to the door cylinders. Four main reservoirs are fitted, mounted vertically against the cab, and there is an additional reservoir for use in conjunction with the emergency brake. Air for the various services is provided by a Holman two-stage compressor, located between the locomotive frames and belt-driven from the main engine crankshaft. The air brake cylinder is mounted horizontally between the locomotive frames adjacent to the compressor, close behind the leading buffer beam. The brake

rigging is of the adjustable type and applies one block on each wheel, whether the air brake or hand brake is in operation. The handbrake itself is of the ordinary screw type, with the handle located in the rear part of the cab.

The Engine

Power is provided by a four-cylinder Fowler-Sanders 4C-type oil engine, set to give a maximum output of 150 b.h.p. at 1,000 r.p.m. The cylinders have a diameter of 7 in. and a stroke of 9 in., and at the top output the piston speed is 1,500 ft. per min., the m.e.p. 85 lb. per sq. in., and the weight 41 lb. per b.h.p. One of the features of the engine design is the special two-way swirl combustion chamber, the purpose of which is to give intimate mixing of fuel and air over a wide speed range, combined with a low fuel injection pressure, easy starting, and a small surface area to volume ratio. The air and fuel mixing is so good that m.e.p.s up to 128 lb. per sq. in. have been attained without a smoky exhaust.

Cast iron is the material used for the crankcase and cylinder block, and both details are provided with inspection doors. The cylinder heads are individual castings of nickel cast iron and contain large water spaces. Renewable wet-type liners are inserted in the cylinder block, and they have a nitrogen-hardened surface to give longer working life. The pistons are fitted with three pressure and two scraper rings, and drive the connecting rods through fully-floating casehardened gudgeon pins. The rods themselves are steel stampings and have four-bolt big ends carrying steel-backed whitemetal-lined bearings; gunmetal bushes are used at the small ends. Heat-treated carbon steel is used for the single-piece crankshaft, which is not hollow-bored. Main bearings and crankpins have a diameter of 4¾ in., and the end thrust is taken by the bearing at the flywheel end.

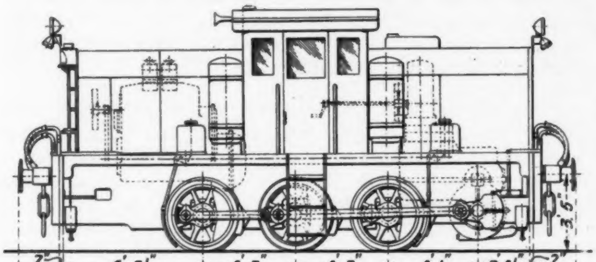
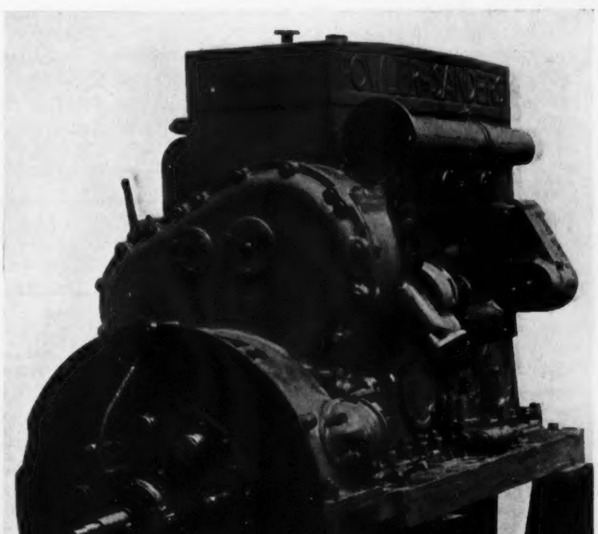


Diagram of 150 *b.h.p.* 31*-ton diesel-mechanical shunter for South Wales*

Each cylinder head carries one inlet and one exhaust valve having automatically-lubricated stem guides, and driven in the usual fashion through push rods and rockers from a casehardened camshaft enclosed in an oil bath. C.A.V.-Bosch fuel injection pumps and nozzles are incorporated, and two big gauze-and-cloth type filters are inserted in the fuel line before the pump. The fuel tank in this particular locomotive has a capacity of 70 gal., and in the cab is kept a suction and delivery hose for filling the tank from barrels or from a storage tank on the ground. The governor is of the centrifugal type, operating on the fuel pump, and is incorporated in the timing gear. Pressure lubrication is on the dry sump system. Oil from an auxiliary tank located away from the engine is led to the pressure pump, by which it is forced to the bearings, and a second pump, driven in tandem with the pressure pump, collects the used oil from the sump and returns it *via* the cooling elements to the auxiliary tank. Cooling water circulation is maintained by a centrifugal pump driven from the timing gear, and the water is passed through a gilled tube radiator mounted on the front of the locomotive and is under thermostatic control. Behind the radiator is a fan belt-driven from the engine crankshaft, and a semi-rotary hand pump, mounted on the outside of the engine bonnet, is included in the circuit. The silencer is located between the locomotive frames at a lower level than the engine, and an exhaust pipe leads thence to the cab roof. Starting of the main engine is effected by a two-cylinder four-stroke Fowler-Sanders 14 b.h.p. engine, which is complete with a clutch, freewheel, and reduction gear. The starting handle for this small engine projects through the back weatherboard of the cab.

The Transmission

The four-speed mechanical transmission is of Fowler's own pattern, and the engine torque is transmitted to the gearbox through a multi-plate dry friction clutch lined with Ferodo, and a cardan shaft with flexible couplings. The clutch is operated by duplicated pedals, one at each side of the cab; full depression of either pedal applies a clutch brake. Dog clutches effect the speed changes in the constant-mesh gears, and are operated by a lever working in a gate. The four steps are proportioned to give track speeds of 3, 6, 10, and 15 m.p.h. with top engine revs. and the corresponding tractive efforts are 13,000, 6,500, 3,900, and 2,600 lb. The gears are of casehardened high-tensile alloy steel mounted on splined shafts of alloy steel, which are carried in ball and roller bearings. Bevel reverse gears are incorporated in the gearbox and are manually controlled by a lever working in a quadrant. The final drive to the jackshaft is by large spur gears. The jackshaft itself is carried in large gunmetal bearings and has keyed to it balanced flycranks which transmit the drive to the rods. The transmission as a whole is located at one end of the locomotive and balances the engine weight at the other end.



150 *b.h.p. four-cylinder four-stroke Fowler-Sanders oil engine for locomotive applications*

BIG DIESEL EXTENSION IN NORWAY

A 2,000-b.h.p. main-line locomotive, triple-car diesel-electric trains, and single-unit railcars are included in the programme for 1939-40

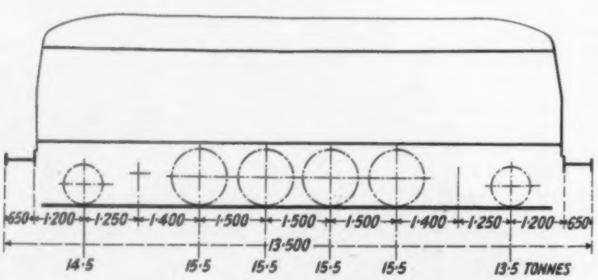
FOR operation over the 308-mile Oslo—Bergen main line, which rises to a height of 4,300 ft. above sea-level, the Norwegian State Railways last year placed an order with the Fried. Krupp A.G. for an express diesel-hydraulic locomotive of 2,000 h.p. This order was placed only after most comprehensive trials with a high-power set of hydraulic transmission, as previously the biggest equipment of this particular type, the Lysholm-Smith, had been of less than 200 b.h.p. at over 1,000 r.p.m. Double-unit diesel locomotives driven from one end will eventually be used, but the 1-BB-1 locomotive now under construction is considered as half of one of the proposed machines, although its power is quite enough for it to work trains of normal weight to the present steam train schedules.

Hydraulic transmission was considered essential because of the weight question, and careful estimates showed that electric transmission would add 30 tons to the weight of a double-unit locomotive, and would naturally increase the price. The prime importance of weight was due not only to the mountainous character of much of the line, over which the locomotive would absorb a good deal of power in propelling itself, but also to the strictly limited maximum axle-load, and on this score it was found that an extra carrying axle would be required if electric transmission was embodied. Delivery of the 2,000 b.h.p. unit is expected by April, 1940, and thorough tests over the line are to be made before further locomotives are ordered.

Power is to be provided by two M.A.N. six-cylinder engines pressure-charged on the Büchi exhaust-gas turbo system to give an output of 1,000 b.h.p. each at 700 r.p.m. The engines will be to the same design as those installed in the second express oil-electric locomotive of the French National Railways (see issue of this Supplement for July 8, 1938, and page 13 of the January 20, 1939, issue), and will have cylinders 300 mm. bore by 380 mm. stroke. Welded steel frames are to be incorporated and the specific weight will be about 15 lb. per b.h.p. The two engines are to be mounted on a common bedplate, and the two 1,000 b.h.p. sets of Krupp (Lysholm-Smith) hydraulic transmission will be arranged at opposite ends of the engine combination. Each set of transmission will drive two axles, and will give a top speed of 100 km.p.h. (62 m.p.h.); operating with the turbo transmission the speed for highest transmission efficiency will be just over 60 km.p.h. (say, 38 m.p.h.), and it is anticipated that it will be at about this speed that the locomotive will ascend the ruling grade, which is almost uninterruptedly at 1 in 47 for approximately 40 miles. A small auxiliary diesel-electric set is to be provided to furnish power for the lighting, brake compressor, and other auxiliary requirements, particularly when the main engines are shut down during long coasting periods.

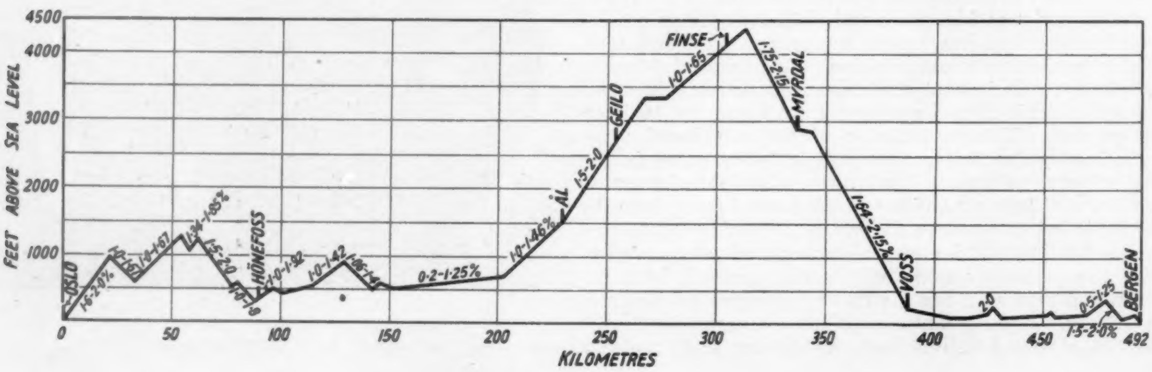
Railcars

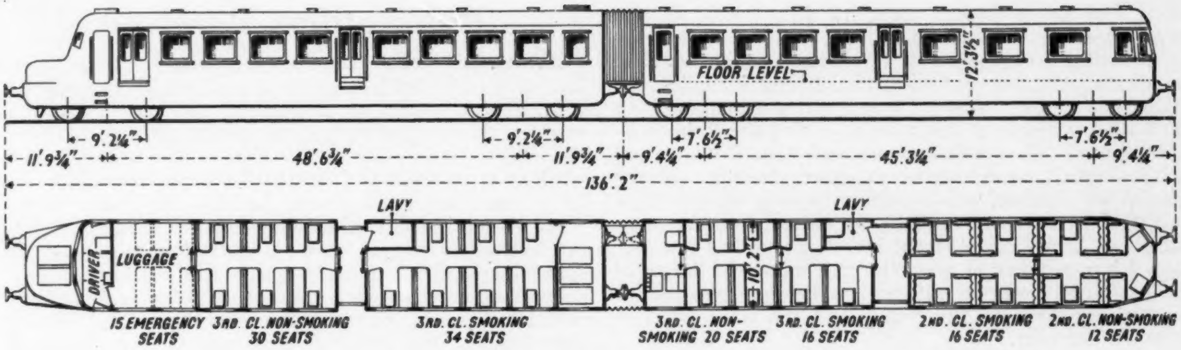
Following on the introduction early last year of three double-bogie railcars, two with mechanical transmission of the Norwegian State Railways' own type and one with Voith double-turbo hydraulic drive, ten further bogie cars with Voith hydraulic transmission have been ordered, and in order to obtain as low a weight as possible, Duralumin is to be used largely in the fabrication of the mechanical portion. Last year's cars are also of light-metal construction and tare 28 tons for a seating capacity of 80 in one class, obtained in a body length of 66½ ft. and an overall width of 10 ft. They were built by Strommens Verkstad A.B.; the two cars with mechanical transmission are equipped with two 150 b.h.p. M.A.N. vertical engines, and the third car, having Voith drive, with two D.W.K. eight-



Left: Outline diagram of 1-BB-1 diesel-hydraulic locomotive of 2,000 b.h.p. for express traffic on the main lines of the Norwegian State Railways

Below: Simplified gradient profile of the Oslo—Bergen main line, over which the 2,000-b.h.p. diesel locomotive will run in regular service





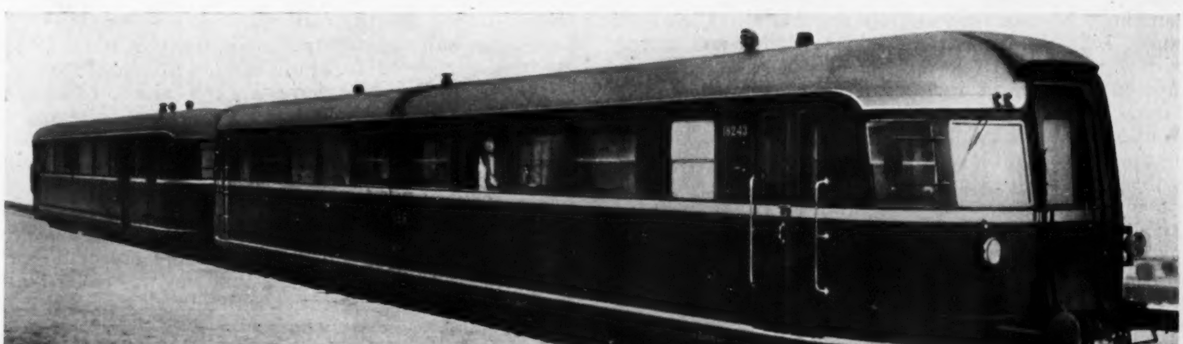
A proposed design for a 600-b.h.p. diesel-electric train, composed of one double-engined railcar and one non-driving trailer, to run between Oslo and Trondheim

cylinder horizontal engines, limited to 170 b.h.p. each at 1,500 r.p.m. Both the engines are mounted on the underframe and drive only one axle of each bogie. Both types have a top speed of 100 km.p.h. (62 m.p.h.); up a 1 in 56 grade they can maintain 75 km.p.h. (46 m.p.h.), these performances being with one trailer. Two trailers can be hauled on slower schedules. Knorr compressed air brakes are incorporated. These cars, which are reported to have cost £10,000 each, are used mainly for passenger service on the Nordland line between Trondheim and Grong. D.W.K. engines are to be used in the new cars.

Multi-Unit Trains

The main feature of this year's programme will be the placing of an order with Norwegian manufacturers for a batch of triple-car diesel-electric express trains for use on the Bergen and Trondheim lines, partly as a result of the performances put up by a Danish railcar set on the Trondheim, Bergen, and Kristiansand routes, when on loan to the Norwegian State Railways towards the end of last year. It was originally hoped that one of the Lyntog sets could have been run over Norwegian lines, but owing to the relatively high axle load it was found desirable to send over two of the MO-type railcars and run them with a trailer between. The time taken by this set between Oslo and Bergen was 6 hr. 55 min., and a speed of 60 km.p.h. (37 m.p.h.) was maintained up the 1 in 47-50 grade. The total weight of the train was 153 tons.

Some time ago serious proposals were made by Professor Heje in the Norwegian journal *Teknisk Ukeblad* for the introduction of a twin-unit diesel train to run between Oslo and Trondheim in about 7¼ hr. This idea appears to have given way to another comprising the triple-car sets to be ordered, but the proposals and calculations of Professor Heje are of some interest. As the through traffic on the Trondheim line could never be very heavy, railcar services should be very suitable. The gradients north of Trondheim would also show them up to advantage. When eventually completed throughout between Oslo and Bodö, the route will be 800 miles long. The design prepared by Professor Heje is as shown at the top of this page and comprises one railcar and a permanently-coupled trailer. The railcar design is modelled on that of the Decauville vehicles running on the Savoy lines of the French National Railways, and would be fitted with two Saurer 12-cylinder vee 300-b.h.p. engines, each of which, together with a directly-driven generator and two nose-suspended traction motors, is mounted on one bogie. Both wheel and drum brakes are proposed, and also facilities for rheostatic braking. The trailer would have air brakes controlled through the railcar. Steam heating with an exhaust gas boiler is proposed. The estimated weight of a railcar is 41 metric tons tare and just over 50 metric tons gross. The trailer will be built along the lines of the present Norwegian light alloy railcar trailers and would tare only about 16 metric tons; it should have a gross weight of about 24 tons. The general ensemble would have a streamlined form together with a full width outer vestibule connection. The total seating capacity including the emergency seats in the luggage compartment is over 140, and if necessary the second class accommodation could be replaced by third, when the total would rise to about



300-b.h.p. double-engined light-alloy railcar and special light-alloy trailer, Norwegian State Railways

160. The width is just over 10 ft., which is the normal figure in Norway for railcars.

Calculating the speeds over the various sections of line, an efficiency through the transmission and including the auxiliaries of about 0·7 is estimated, giving a total of about 420 b.h.p. available at the wheels. Using the train resistance formula due to Leitzmann and Von Borries, and making certain modifications to cover the effect of the streamlined contour, the maximum speeds with a train weight of 74 tons over various sections of line are as in Table I. According to recent investigations in Germany, the rail h.p. required to maintain such speeds up the given grades varies between 435 and 455, corresponding to an efficiency between the engine and the wheel rims of 72 to 76 per cent.

Possible Speeds

Taking the Oslo—Trondheim line as a whole, the lowest average speeds will be found over the Hamar—Lillehammer and Stören—Trondheim divisions over which the calculated averages are 77 and 78 km.p.h. respectively. On the first-named section there are many loops where speed must be reduced and the line was originally built as a second-class route. The Stören—Trondheim section was built originally as a narrow-gauge line and although the gauge was changed to standard at a later date, the line still retains numerous sharp curves and there are grades of 1·8 and 1·9 per cent. on quite a large proportion of the length. The section showing the highest average speed in both directions is that between Lillehammer and Otta,

TABLE I

Gradient per cent.	Section of line	Speed km.p.h.
2·63	Oslo-Bryn	55
2·5		57
1·9	Melhus-Heimdal	72
	Maximum gradient	
1·8	Trondheim-Dombås, ..	75·6
1·6	Sell-Brennhaug, and Dovre-Dombås	82·5
1·5		86·5
1·4		90
1·3		95
1·2		100

over which an average of 85 km.p.h. is proposed; even a further improvement might be made by realigning certain curves between Ringebu and Harpefoss. Despite the 2·6 per cent. grade up to Bryn, a fairly high average speed could be maintained over the Oslo—Hamar section. Assuming a 15-min. stop at Dombås, and 1 min. each at Hamar, Lillehammer, Otta, Hjerkinn, Opdal, and Stören and a 3 per cent. margin on the actual running time, the proposed schedule in each direction amounts to 7 hr. 16 min. Working on a similar basis, the Oslo—Mosjøen run of 596 miles could be accomplished in about 12¾ hr., and the Oslo—Bodö journey of 801½ miles in about 17 hr. By the use of such railcar trains, Professor Heje considers that end-to-end speeds such as these could be attained without necessitating any expensive track realigning or the laying of heavier rails. He considers that if a service were introduced, one return trip a day in each direction could be made, operating one car from each end and holding a third in reserve. The reserve set could be used on certain occasions for special or excursion trains, as is done in Switzerland. The design, as proposed, is not reversible, and it would be necessary to insert reversing loops in order to avoid uncoupling and making use of turntables, but the use of a driving trailer would enable this difficulty to be overcome.

Publications Received

A.E.C. Visitors' Book.—Something new in trade literature is to hand from the Associated Equipment Co. Ltd., in the form of an illustrated guide to the Southall works. By a preliminary study of this 32-page brochure the visitor already has a fair idea of the works layout, what he is to see, and just where are the items in which he is most interested, before he signs his name in the other visitors' book at the door. The full range of A.E.C. productive activity is covered, including railcars, high-speed oil engines, epicyclic gearboxes, and bus chassis assembly, as well as such things as the bus test gradient, engine test house, and the engine experimental and research department. The bus test gradient, of 1 in 9, forms part of a 1¼-mile bus test track encircling the works, part of which is equipped with overhead wires for trolley-bus testing.

Diesel Engines. By B. J. von Bongart. London: Chapman & Hall Limited, 11, Henrietta Street, W.C.2. 9¼ in. by 6¼ in. by 1 in. 335 pp. Illustrated, Price 21s. net.—We have always been led to believe that, taking North America as a whole, the intelligence of the present-day inhabitants did not rise above the general level found in Europe. But Mr. von Bongart has made us revise our ideas, for he, alone among all authors of books on the oil engine, has found a lower class than students. In his preface he expresses the hope that his book will be of use to the layman, but, to use a phrase common over the water, it would be "some" layman to whom this book would appeal. American in its origin and general scope, the book nevertheless contains a large amount of information relative to English and Continental practice, particularly as to combustion chamber and fuel injection equipment. The chapter on thermodynamics is perhaps a little different from those usually found in the general run of oil-engine books at the present time, but it certainly does not suffer thereby. It is written in a clear and concise manner and is especially valuable because of its discussion of the air standard formulæ, a simple reference to which will often deflate the claims made for fantastically low fuel consumptions. In the excellent chapters on combustion, fuel oils, and fuel atomisation there is a considerable amount of data which must have been obtained directly from research and experimental investigations, although most of it will be of use to the designer and research worker rather than to the practical engineer or engine user. Much space is devoted to descriptions of the wide variety of fuel injection equipment and combustion chamber designs and to an examination of their characteristics, but in the ensuing chapters on various types of oil engines the material is of a lower standard. Many of the half-tone illustrations in this part of the book have been made from block pulls and not from photographs, and the descriptions themselves are too brief to be of use. The chapter on aircraft diesels is largely out of date, and it seems as if we are never to hear the last of the Packard radial, Beardmore Tornado and early Bristol Phoenix engines. Moreover, the Maybach 12-cylinder 410-b.h.p. oil engine has never been an aircraft type; it has always been purely a railway model. But in the short railway section of this book only American makes are described, and even then the celebrated Winton two-stroke with 8-in. by 10-in. cylinders is cut off virtually without mention. Apart from the deficiency in certain half-tones as noted above, the book is well produced, and with about half a dozen exceptions the line blocks are quite clear, although the drawings are not sprinkled with dimensions. A table of piston displacements, a short bibliography, principally of German works, and an index complete the book.

An Advance in Shunting Locomotive Design

Simplified controls and automatic gear change

SOMETHING surpassing the simplicity of steam locomotive controls has been obtained in a shunting locomotive built by F. C. Hibberd & Co. Ltd. for operation in the yard of the Crossley-Premier works at Sandiacre. By the incorporation of the Freeborn gearbox, with its automatic gear-changing feature, the throttle handle is all that is necessary to control the motion in any one direction, and the complete driving controls are limited to the throttle, reverse, and brake handles. Moreover, the break in tractive effort at each gear change is virtually nil, and in this particular locomotive we found it practically impossible to tell the point of gear change when the locomotive was running light, thanks to the provision of five gear steps from zero up to the top speed of 10¼ m.p.h., *viz.*, 3, 4, 5½, 7½, and 10¼ m.p.h. The Freeborn box has successfully passed its preliminary trials, and will be given several months service testing on this Hibberd locomotive before normal production is begun. Each reduction gear in this box comprises a driving and a driven gear on a central shaft coupled by pinions carried on a normally free member. This member engages a fixed casing when in operation, but when the load is small enough to be dealt with by one less ratio, it is disengaged and locked to the central shaft.

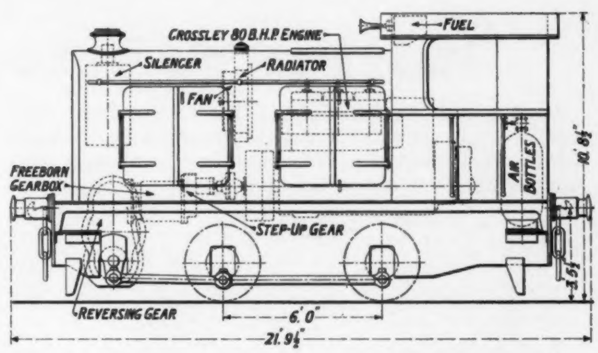
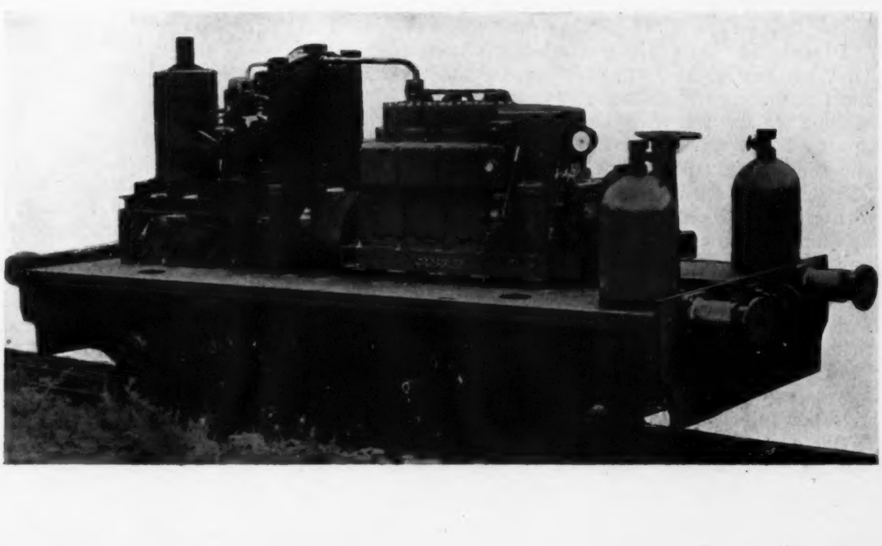


Diagram of 23-ton diesel-mechanical shunter powered by two-stroke engine

The locomotive itself is of robust construction, and is powered by an equally sturdy Crossley two-stroke engine developing 82 b.h.p. at 500 r.p.m. in three 7 in. by 9 in. cylinders. The engine torque is maintained almost constant over the running speed range, and is transmitted through a cardan shaft and step-up gears to the gearbox, and thence through Hibberd reversing gears to the jackshaft, which like the gearshafts, is carried on SKF roller bearings. Starting is effected by air provided by a Hamworthy compressor driven by a small Crossley four-stroke engine; this starting set charges two bottles from which air is let out for engine starting, and, through a reducing valve, for the Westinghouse straight air brake. The Reliance radiator is mounted midway along the bonnet, just behind the compressor set, and has a fan belt-driven from the engine. The engine is carried on substantial channels secured to the locomotive frame, and the auxiliaries are mounted on separate framework. The 40-gal. fuel tank is mounted in the cab above the engine scavenge pump. C.A.V.-Bosch electrical equipment, including head and cab lamps, is fitted, and is fed from an Exide battery. The throttle and brake handles are duplicated, so that the locomotive can be driven from either side of the cab.

Above: General view of the 82 b.h.p. Hibberd - Crossley shunting locomotive



Right: View of locomotive without bonnet and cab, showing the two-stroke engine and air bottles to the right, the radiator and starting set in the middle, the silencer to the left, and below the silencer the reversing gear and gearbox

NOTES AND NEWS

Danish Railcar Extension.—The Danish State Railways recently took delivery of ten more of the standard MO-type 550-b.h.p. diesel-electric railcars, and have since ordered a further nine to the same design.

German Diesel Train Mileage.—From going into service on July 1, 1938, until the end of that year, the first few of the 14 new triple-car 1,200-b.h.p. diesel-electric trains of the Reichsbahn (see issue of this Supplement for September 2), averaged 62,000 miles each.

Zephyr Acceleration.—One of the Twin Cities Zephyrs of the Chicago, Burlington & Quincy Railroad has been accelerated by 15 min. to cover the 431 miles between Chicago and St. Paul in 6¼ hr., at an average of 68·9 m.p.h.; the ensuing 10 miles on to Minneapolis are allowed 30 min. as before, including the St. Paul stop.

S.L.M. Gearboxes.—In 1935 the then five big French railways ordered a total of 41 of the standard cars, all of which were fitted with S.L.M.-Winterthur gearboxes. Including seven spare sets, the number of transmissions ordered was 80, and they have now covered a total distance of over 10,000,000 km. (6,200,000 miles).

Tallulah's Launch.—Tallulah Bankhead, one-time stage idol of London crowds, broke the traditional bottle of champagne over the nose of the latest 3,600-b.h.p. diesel locomotive of the Baltimore & Ohio Railroad, when that line's Capitol Limited train started on its first journey between Washington and Chicago composed of fully streamlined stock.

Rhodesian Railcars.—The Rhodesian Railways have ordered from the Metropolitan-Cammell Carriage & Wagon Co. Ltd. two 480-b.h.p. twin-car articulated diesel-mechanical trains, two 240-b.h.p. single-unit railcars, and one spare power bogie, all of the Ganz type. The trains will be powered by two 240-b.h.p. engines. Accommodation is to be provided for both native and European passengers, and for luggage and light freight.

Australian Shunter.—The Queensland Government Railways are building at the Ipswich works a four-wheeled diesel locomotive for shunting and for short-haul service with 100-ton trains. It is to be operated at an altitude 3,000 ft. above sea-level. The power unit is to be a Gardner 6L3 engine developing 150 b.h.p. at sea-level, and it will drive the wheels through a Vulcan-Sinclair fluid coupling and a four-speed Wilson gearbox.

Diesels for Africa.—An order has been placed with D. Wickham & Co. Ltd., of Ware, by the Crown Agents for the Colonies for three metre-gauge diesel-mechanical railcars for the Kenya & Uganda Railways. The engines are to be of the Saurer BXD type pressure-charged on the Büchi exhaust-gas turbo system to give an output of 225 b.h.p. at sea-level and 180 b.h.p. at the maximum altitude at which the cars will operate. The seating accommodation is to be for 6 first class and 52 third class passengers.

West Australian Railcars.—The six diesel-electric railcars of the West Australian Government Railways (see issues of this Supplement for April 16, 1937, and September 2, 1938) during the first four or five months of their regular service, covered an aggregate of 140,302 miles. The earnings per mile were 23·8d., and the operating expenses 9·49d. per mile. The total number of passengers carried was 35,763. Gross earnings for the period were £13,931, working expenses £5,552, interest charges £1,088, and depreciation £1,752, leaving a surplus of £5,539 after all these accounts had been met.

South American Railcar Order.—A dozen broad-gauge double-bogie diesel-mechanical railcars are being built by Ganz & Co., of Budapest, for the Buenos Ayres Pacific Railway. They are to be powered by 240-b.h.p. engines, and the design will be generally similar to that of the Ganz cars supplied at the end of 1937.

Paris-Lille Diesels.—One of the well-known ex-Nord triple-car diesel trains has been running as a four-car set with a total of 180 seats, the normal three-car formation having insufficient seating accommodation, following the withdrawal of certain train services as an economy measure. The extra trailer vehicle was taken from one of the two trains built in 1934, and the two power cars remaining from that set are now operating on the Lille-Dunkerque and Dunkerque-Arras services, where they have replaced Michelin railcars, which, in their turn, have become too small for the less frequent services.

New French Railcars.—The Région du Sud-Est (ex-P.L.M.) of the French National Railways has put into traffic in the Besançon area, five new double-bogie diesel-mechanical railcars, built by De Dietrich. They are powered by two bogie-mounted C.L.M.-Junkers two-stroke opposed-piston engines, which drive Mylius-type five-speed gearboxes, giving track speeds of 27, 46, 70, 100, and 135 km. p.h. with the engine running at 1,500 r.p.m. The cars contain 70 seats and 41 standing places, together with a lavatory and 70 sq. ft. of luggage space. The tare weight is 41·5 metric tons, and up to 50 tons of trailers can be hauled over lines with gradients as steep as 1 in 40.

D.E.U.A. Annual Dinner.—The twenty-sixth annual dinner of the Diesel Engine Users Association was held at the Connaught Rooms, on Wednesday, February 1, with the President, Mr. George E. Windeler, in the chair. Lieut.-Colonel J. T. C. Moore-Brabazon, in proposing the toast of "The Association," referred to the strides made by the internal-combustion engine in general and the diesel engine in particular; on the transport side, he mentioned omnibuses, 80 per cent. of which, he said, were now diesel-driven. There were two things which he strongly advocated—one was concentration on a solid-fuel injection diesel, and the other was compulsory use of diesel engines on aeroplanes. Mr. George E. Windeler, in replying to the toast, said that the prince of prime movers—the diesel engine—had called for a high standard of scientific knowledge and was a very hard master. He stressed particularly the co-operative spirit of the association, which, by calling in users, designers, and inventors, had produced a state of efficiency, and, more important still, one of reliability. Mr. T. Hornbuckle proposed the toast of "The Guests," many of whom, he said, had not only carried out a great deal of sound engineering practice, but had also conducted interesting research work; he welcomed the opportunity they had afforded for co-operation, as well as the valuable information they had placed at the disposal of the Association. Mr. Percy C. Kidner, President of the Institution of Automobile Engineers, replying on behalf of the guests, referred to the invaluable reports issued by the D.E.U.A., and the large amount of support it had given to research work, which was of such fundamental importance. During the evening, the Percy Still Medal was presented to the 1938 winner, Mr. H. V. Stead, M.Sc.

Diesel Railway Traction

Main-Line Diesel Performance

FROM going into regular service over the main line of the Région du Sud Est of the French National Railways on July 5, 1938, until the end of that year, the first of the two 4,400-b.h.p. diesel-electric locomotives built for the ex-P.L.M. Railway (see issue of this Supplement for July 8, 1938) covered a mileage of 112,650 km. (70,000 miles), equivalent to a yearly distance of 260,000 km. (162,000 miles), made up principally by a daily return trip between Paris and Lyons with trains 13 and 16. On October 24 the locomotive was brought into the shops for its first routine partial overhaul, having then covered 80,947 km. (50,000 miles) and performed 39,977,000 trailing *tonne*-km. (24,500,000 trailing ton-miles). During this period the fuel consumption averaged 3·24 kg. per train-km. (11·45 lb. per train-mile) with trains weighing nearly 500 tons and operated at schedule speeds approximating to the mile-a-minute mark. The engine lubricating oil consumption has averaged 0.04 gr. per *tonne*-km. On a special return trip between Paris and Marseilles with a trailing load averaging 460 tons between Paris and Avignon and 530 tons between Avignon and Marseilles, the total fuel consumption was 4,750 kg. (4·68 tons) for the 1,074 miles. The two 2,200-b.h.p. 24-cylinder Sulzer engines were in an excellent state at the 50,000 mile overhaul. One or two piston rings, four valve springs, three valve guides and one fuel injector were practically the only renewals necessary. Four big-end and three main bearings were dismantled and were in such a good state that it was not considered necessary to take down the remainder. In no case during the period under review was the locomotive stopped because of any engine defect.

Progress in America

THERE is considerable activity in the United States just now in the application of oil engines to rail traction, principally by the construction of heavy shunting locomotives. For example, the Reading and Central of New Jersey Railroads have ordered 15 diesel-electric locomotives for use on both lines. The Seaboard Railway has acquired a seven-car stainless steel Budd train which is to be hauled by a 2,000-b.h.p. Electro-Motive Corporation diesel-electric locomotive. The Chicago, Rock Island & Pacific Railroad has extended its express diesel-hauled Rocket train between Kansas City and Oklahoma City, to Dallas and Forth Worth, Texas. Three 110-ton oil-electric shunting locomotives, built by the Baldwin Locomotive Works, have been put into traffic by the New Orleans Public Belt Railroad. They are used mainly in yard work, but also operate a freight transfer service over the Mississippi River bridge, which has approach grades of 1·25 per cent. or nearly 2¼ miles. When handling heavy trains over the bridge two of the locomotives are coupled in multiple-unit. Power is provided by a 900-h.p. eight-cylinder four-stroke De La Vergne engine running at 600 r.p.m. The maximum tractive effort is 73,000 lb., and on the continuous rating of the electrical equipment 29,500 lb. at 9 m.p.h.; on the one-hour rating it is 40,000 lb. at 5¾ m.p.h. The bogie wheelbase is 8 ft. 4 in., and curves of 130 ft. radius can be negotiated. The Erie Railroad has ordered two 600-b.h.p. and the Fort Worth Belt Railroad one Electro-Motive diesel-electric shunting locomotives. The Kansas City Terminal has ordered two 900-b.h.p. diesel-electric switchers from the same maker, and, as briefly recorded in the issue of this Supplement for January 20, the Atchison Topeka & Santa Fé Railroad at the end of 1938 ordered 30 oil-electric switching locomotives, some of 600 b.h.p. and some of 900 b.h.p., the aggregate price being in the neighbourhood of $2,250,000. Purchase of further equipment is now under consideration. Again, the Union Pacific is to increase its stock of main-line locomotives by a twin-unit 4,000-b.h.p. plant, intended as a spare for the various Chicago-Pacific high-speed streamlined services. The C. & N.W. Railroad, which has worked its celebrated "400" express between Chicago and the Twin Cities by steam for some years, is now changing over to diesel.

The Missouri Pacific Railroad is seeking approval to purchase at a cost of $198,000 two 900-b.h.p. oil-electric locomotives for use on the Union-Lincoln route, and three 900-b.h.p. and two 600-b.h.p. heavy switchers for operation in and around the St. Louis terminal at a cost of $381,000. Other locomotives for similar duties are the three Alco oil-electric locomotives for the Minnesota Transfer lines. Finally, an extra car has been added to each of the two City of Denver diesel trains on the Union Pacific Railroad, and the two-unit 2,400-b.h.p. locomotives have been increased in power by another 1,200-b.h.p. unit, giving a total of 3,600 b.h.p. available for the 11-car train plus triple-unit locomotive. Each of these trains and its 2,400-b.h.p. locomotive has now covered over 1,030,000 miles since being placed in traffic in June, 1936.

Danish Diesel Service Improvements

THE fast Nordpilen diesel service between Frederikshavn and Flensburg will run as a four-coach train from next summer, and will comprise, in sequence, a railcar, two trailers, and a railcar. When coming from the south the train will be split at Hjørring, one half proceeding to Frederikshavn as hitherto, and the other half proceeding over the private Hjørring—Hirtshals line to Hirtshals, where it will connect with the steamship to Kristianssand, in Norway. In the opposite direction the two-coach trains will be combined at Hjørring and continue south as one train. The two trains arrive at Hjørring from opposite ends of the station, and all that is required is therefore that one of the halves runs through the station and backs on to the other half; going north the two halves can leave immediately on being uncoupled.

The new three-track diesel ferry for the Great Belt service has been launched and named *Storebælt*. It will be ready in time for the summer timetable and will enable a considerable improvement to be made in the schedules of the three morning Lyntogs from Copenhagen. At present all three trains are taken across on the same ferry, and as they all have to use the same track on both sides of the Belt this means long stops at both sides for the trains which arrive first and depart last (7 min. at each end for Østjyden and 14 min. at each end for Vesterhavet). From next summer the Østjyden will have its own ferry and run in front of the Kronjyden to Aarhus, thus eliminating the waits at Korsør and Nyborg and at the same time giving an improved service from Odense and Fredericia to North Jutland. The Vesterhavet will save half of its present waiting times at the ferry terminals; it will continue to be transferred by the same ferry as the Kronjyden.

THE LYSHOLM-SMITH HYDRAULIC TRANSMISSION

Made by licensees in Sweden, England, Germany, and America, this well-known turbo-type partial-hydraulic system is advancing in the practicable range of power and torque

HITHERTO used in service only in conjunction with engines of under 320 b.h.p., generally running at speeds of well over 1,000 r.p.m., the Lysholm-Smith type of partial-hydraulic turbo-converter transmission has been given a big step forward in its application to rail traction duties by the decision to incorporate two sets to transmit 1,000 b.h.p. each at 700 r.p.m. in the main-line locomotive now being built for the Norwegian State Railways. Careful tests were undertaken with a Lysholm-Krupp transmission of this power before the order was placed.

Elements of the System

Consisting essentially of a co-axial pump impeller and turbine through which fluid is circulated, the converter is a development of the Föttinger system. As made in England by Leyland Motors Limited, the Lysholm-Smith transmission comprises a double-acting friction clutch, a hydraulic turbo torque converter, and a couple of free-wheels. The converter automatically multiplies the input torque according to the demand at the output shaft up to a ratio of approximately 5 to 1. When no torque multiplication is required the drive can be taken directly through the centre of the converter to the output shaft; the rotating parts of the converter are then allowed to come to rest through the provision of a free-wheel in the converter drive (see Fig. 1) and this also allows over-running by the output shaft when the converter drive is in use. A second free-wheel allows of over-running with direct drive in operation, so that the vehicle can coast in either converter or direct drive.

In both types of drive the torque is transmitted through a friction clutch, one side of which is engaged for converter drive and the other for direct drive. There is also a middle, or neutral, position, which, incidentally, can be used if the vehicle is being hauled. A double-acting air cylinder mounted on the clutch housing is used to provide and maintain the requisite position, and is governed by electro-pneumatic valves. The clutch is not used to start the vehicle, but is only put in or out at a change-over from one form of drive to the other, when the engine speed is momentarily adjusted.

As with the general run of turbo transmissions, the converter drive is used from zero up to 55-66 per cent. of maximum track speed, over which range the tractive effort drops fairly quickly. In shape and magnitude the efficiency curve of the converter follows that of a normal electric transmission fairly closely. A reasonably flat shape over the principal working range of the converter has been obtained in the Lysholm-Smith system by means of improved multi-stage turbine blading, which enables the torque-speed range to become automatically variable with a satisfactory efficiency over fairly wide limits. When running at different torque-speed ratios the blading losses due to the varying inlet angles are the most important, and account for nearly the whole loss at the stalling point and at racing speed.

Controlled blades in the pump element are an improvement and give an enhanced starting torque over the usual 5 to 1 ratio of fixed-blade types. The blades are adjusted by an axially-movable splined sleeve; with the blades

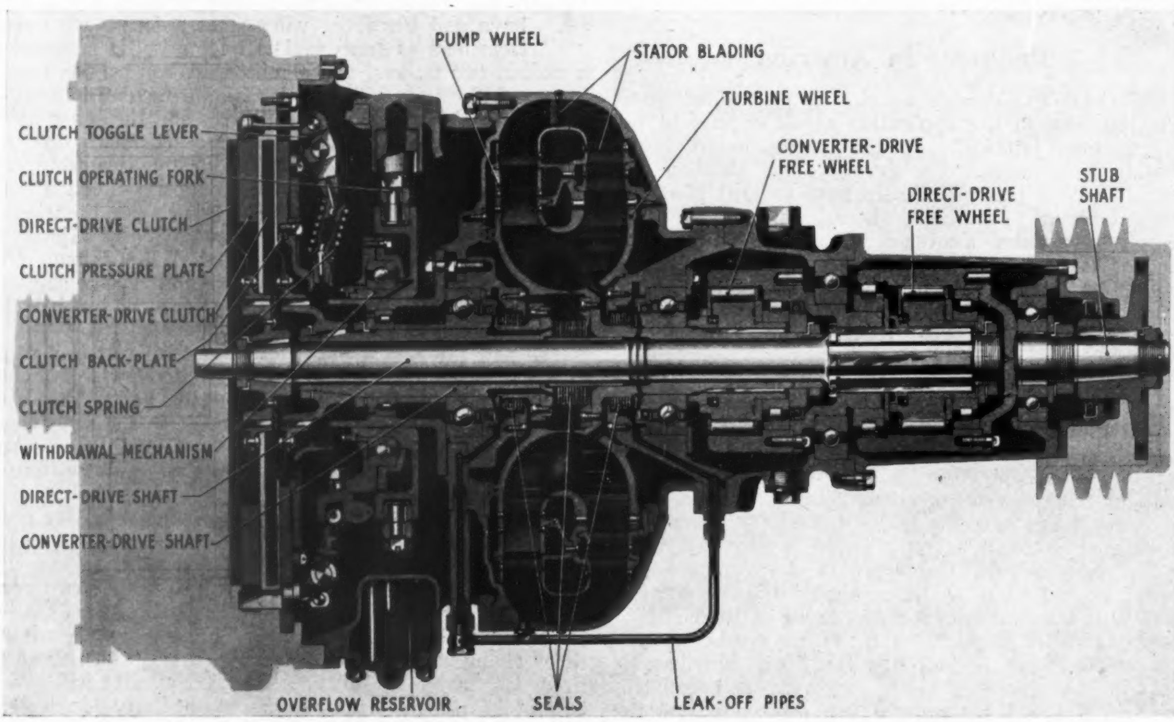
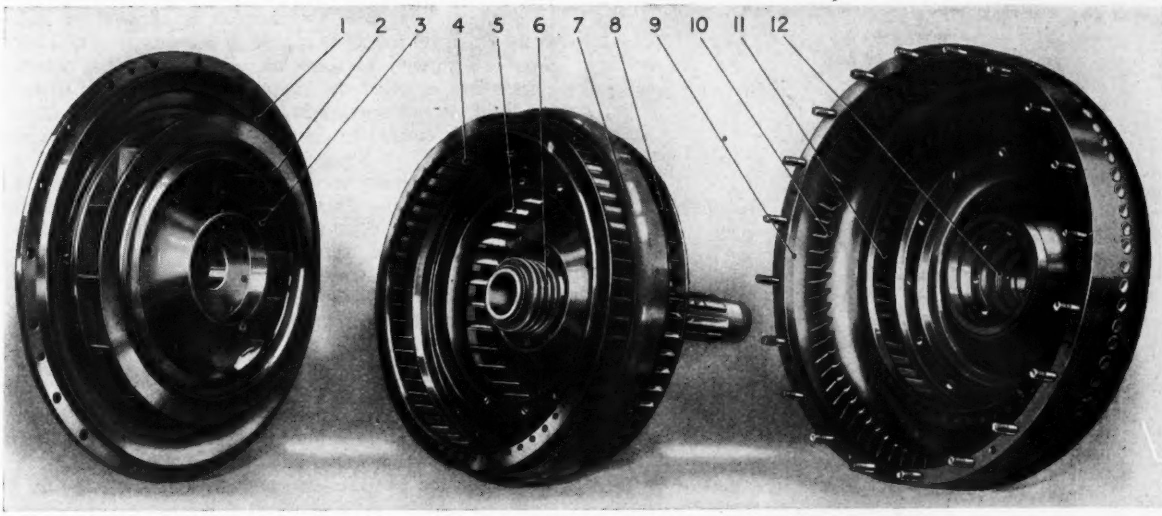


Fig. 1. Section through Leyland transmission, showing double friction clutch, hydraulic converter, and two free-wheels



1—Front cover plate
2—Pump wheel assembly
3—Pump wheel blades
4—1st stage turbine blades
5—3rd stage turbine blades
6—Centre seal
7—Turbine wheel assembly
8—2nd stage turbine blades
9—Converter casing assembly
10—1st stage guide blades
11—2nd stage guide blades
12—Rear seal

Fig. 2. The dismantled components of the Lysholm-Smith hydraulic torque converter

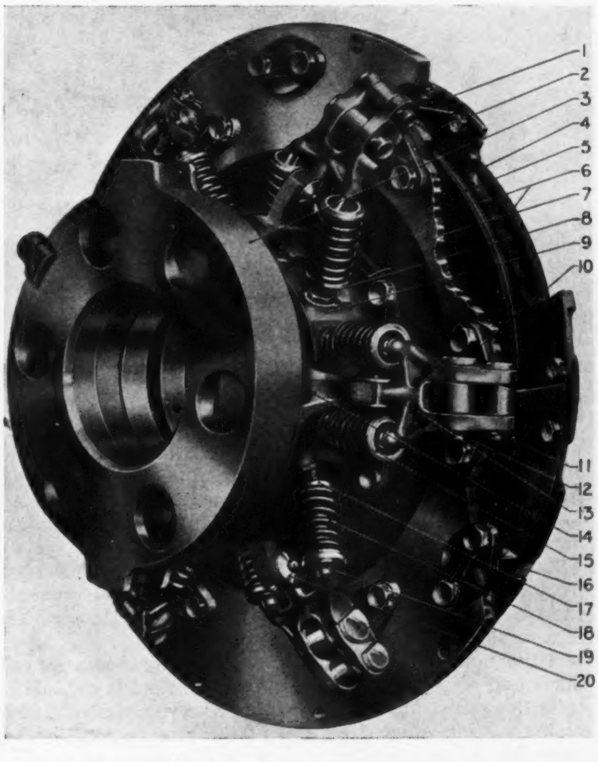
closed there is practically no secondary torque and at the other end of the scale it is possible to load the engine above its normal maximum if desired. Adjustable blades are a feature of the Lysholm-Smith transmission as made by the Variable Speed Gear Co. Ltd., and a set of this type to take up 400 b.h.p. at 700 r.p.m. has been tried.

In the Leyland form, the two plate clutches are carried on two large splined hubs (see Fig. 1), keyed on the taper ends of two concentric shafts; a single pressure plate, housed between the two clutch plates, serves to engage the desired drive. The pressure is supplied by 12 springs (see Fig. 3), operating toggle levers so arranged that as the liners wear the pressure increases, thus obviating slip due to partly-worn liners. The inner clutch plate (Fig. 1) is mounted on a solid shaft, which passes right through the unit and is connected to the propeller shaft by a coupling and companion flange. This clutch, when engaged, gives a direct drive. The outer clutch plate is similarly mounted on a hollow shaft which carries the converter pump wheel. When this clutch is engaged the drive is taken through the converter. The pressure plate (Fig. 3) is located on three driving pegs and is held in engagement by the 12 springs acting through the toggle levers, the tips of which are located in the withdrawal housing jaws. The operating fork (Fig. 1) is carried in bushes located in the clutch housing and operates through a large withdrawal bearing which is lubricated from a nipple on the clutch housing.

Converter Operation

Essentially the torque converter is a three-stage reaction turbine with the fluid operating in a closed circuit. The pump wheel, shown in Figs. 1 and 2, is driven through the clutch, and is of the centrifugal type. The turbine wheel is provided with three sets of blades and is mounted on a hollow shaft which transmits the drive through the free-wheel. Two sets of guide blades are interposed between the first and second and second and third stages of the turbine wheel.

The fluid, which completely fills the converter casing, is given velocity by the pump wheel when the engine is speeded up and the energy thus generated turns the turbine



1—Lever for pressure plate
2—Pressure plate
3—Throw-out sleeve
4—Clutch plate (outer)
5—Clutch plate (inner)
6—Clutch liner
7—Driving plate
8—Holder for roller
9—Spring support
10—Toggle lever bracket
11—Toggle lever pivot pin
12—Toggle lever fulcrum pin
13—Toggle lever
14—Withdrawal plate
15—Spring retainer (outer)
16—Driving peg
17—Spring retainer (inner)
18—Clutch spring
19—Spring retainer roller
20—Toggle lever washer

Fig. 3. Double friction clutch and operating mechanism

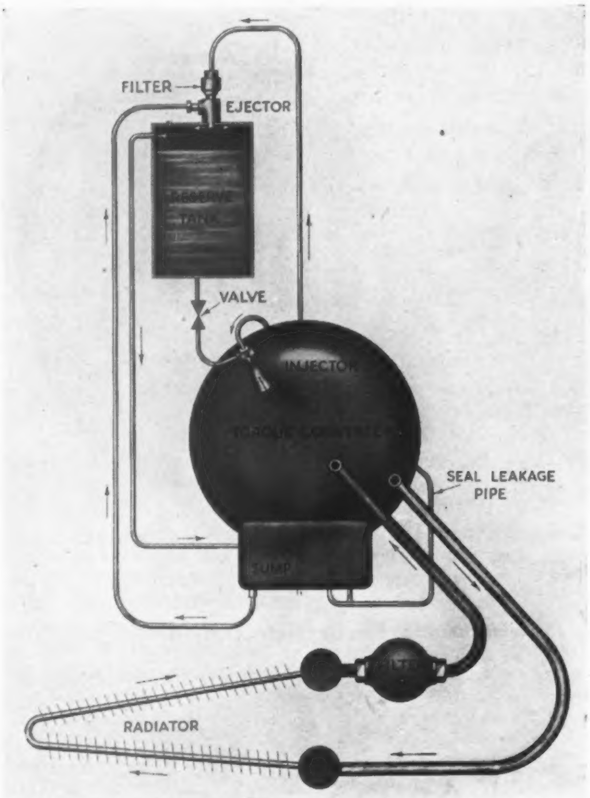


Fig. 4. Diagrammatic representation of fluid circuit in Lysholm-Smith converter

wheel. The guide blading is so arranged that the circulating fluid after impinging on the first-stage turbine blading, is redirected on to the second stage and again on to the third stage. The effect of thus utilising the fluid pressure in three stages is to multiply the engine torque up to a maximum ratio of 5 to 1.

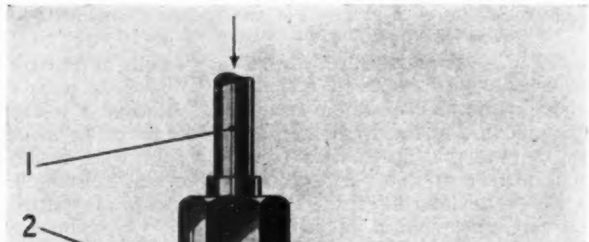
There is a considerable difference in pressure in the fluid before and after leaving the pump wheel and this difference is utilised to operate an injector for replenishing the converter with fluid, and to circulate the fluid through the cooler. The fluid in each case leaves the converter casing from a high-pressure point and for re-entry is directed to the region of lowest pressure. This is clearly shown in the diagram of fluid circulation, Fig. 4.

Excessive leakage of fluid to the bearings is prevented by special seals (Fig. 1) of which a centre seal prevents short-circuiting between the pump wheel and turbine wheel. A very slight leak is permitted to lubricate the seal faces, and the fluid so passing flows through suitably arranged ducts and piping to a small sump. The fluid is evacuated from this sump and returned to the reserve tank by means of the ejector situated on top of the reserve tank. The operation of this ejector, shown in Fig. 5, is automatic. A pressure pipe from the converter is connected to the ejector nozzle, and the fluid in the casing being under pressure, is forced along this pipe, and through the nozzle, thus increasing its velocity, which causes a vacuum to be established in the annular space around the nozzle. This annular space is in communication with the sump by way of a pipe, and fluid that has leaked into the sump is lifted to the reserve tank. A gauze filter protects the nozzle from dirt.

In the event of more fluid passing the seals than the ejector can evacuate, the surplus is allowed to leak on to the track by means of a pipe in the sump. The overflow pipe is arranged to form an air trap so that when the ejector has emptied the sump, air, which tends to oxidise the fluid, is not sucked in. The small quantity of air in the sump is caused to circulate until the fluid again enters the sump.

To keep the torque converter casing full of fluid an injector is provided. This operates by utilising the difference in pressure in the converter casing to cause a flow of fluid through the venturi nozzle. A vacuum is thus established around the annulus, and fluid from the reserve tank is drawn in as shown and delivered under pressure to the converter at a point where pressure is low. The pressure in the converter is limited by the pressure-relief valve, which cuts off the supply by by-passing fluid when the casing is full.

Under extreme conditions of operation the fluid is heated up somewhat and is liable to gasify. To prevent the temperature becoming excessive a special radiator is provided and connected by pipes to the high and low pressure sides of the converter. An efficient filter is provided between the radiator and the point of re-entry to the converter. Gas which forms while the converter is running is automatically evacuated by the ejector.



1—Pressure pipe
2—Ejector filter cover
3—Ejector filter
4—Ejector filter holder
5—Suction pipe
6—Suction pipe union
7—Ejector nozzle
8—Diffuser
9—Ejector holder
10—Reserve tank

Fig. 5. Section through the fluid ejector

AMERICAN SHUNTING LOCOMOTIVE COSTS

Figures from an eastern railroad

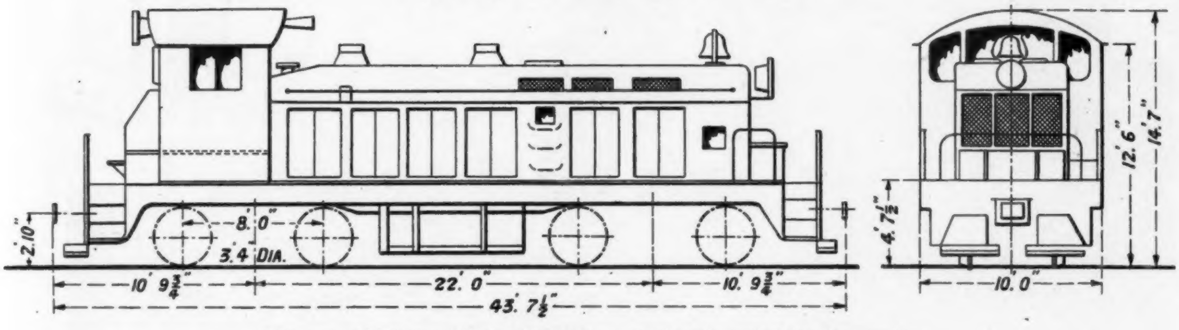


Diagram of Electro-Motive 900-b.h.p. oil-electric switching locomotive

AMONG the earliest lines in the United States to acquire diesel-electric shunting locomotives was the Lehigh Valley Railroad, whose experience dates back more than a dozen years to the time when a double-bogie 53-ton 300-b.h.p. Ingersoll-Rand locomotive with a starting tractive effort of 36,000 lb. was set to work. This locomotive had a driving cab at each end, and was of the then standard type made conjointly by Ingersoll-Rand, General Electric and Alco. In 1931-32 three 300-b.h.p. Alco locomotives with Alco-McIntosh & Seymour engines were bought, and in 1933 one 600-b.h.p. similar locomotive was acquired.

Within the last two years or so, ten further oil-electric shunting locomotives have been put into traffic. They are of the Electro-Motive Corporation's build and are powered by Winton two-stroke engines. Two of the locomotives have an eight-cylinder 600-b.h.p. vertical engine and eight have a 12-cylinder vee 900-b.h.p. model. Both are of the Winton standard type with 8 in. by 10 in. cylinders, a speed of 750 r.p.m., and a weight of 21 lb. per b.h.p. The radiator is located at one end of the locomotive and is provided with an electrically-driven fan. The fuel tank of both types has a capacity of 600 U.S. gal. All the electrical equipment is of General Electric manufacture and comprises a directly-driven 535-kW. main generator giving a voltage of 100 to 700, a 130-kW. auxiliary generator, and four 300/600-volt 214-kW. nose-suspended traction motors driving the 40-in. wheels through spur gears with a ratio of 4·25 to 1.

The 900-b.h.p. locomotives weigh 254,700 lb. and the 600-b.h.p. units 204,000 lb. The respective starting tractive efforts are 64,000 and 60,000 lb., and the factors of adhesion 4·0 and 3·4. The rolled steel disc wheels of 40-in. diameter and the wheelbase particulars are the same for both types, as is the top speed of 40 m.p.h. Westinghouse type 14-EL air brakes are incorporated, with a train line pressure of 70 lb. per sq. in., a main reservoir pressure of 120 lb. per sq. in., and with a motor-driven compressor set with a capacity of 167 cu. ft. per min.

For the period covered by the table of operating costs reproduced at the foot of this page, the two 600-b.h.p. and the first two of the 900-b.h.p. locomotives were operating 6,100 to 6,750 hr. a year at an operating and maintenance cost averaging $1·422 an hour for the smaller locomotives and $1·642 an hour for the 900-b.h.p. size. The remaining 900 b.h.p. locomotives, in somewhat different service, were working at the rate of 4,000 to 5,000 hr. a year.

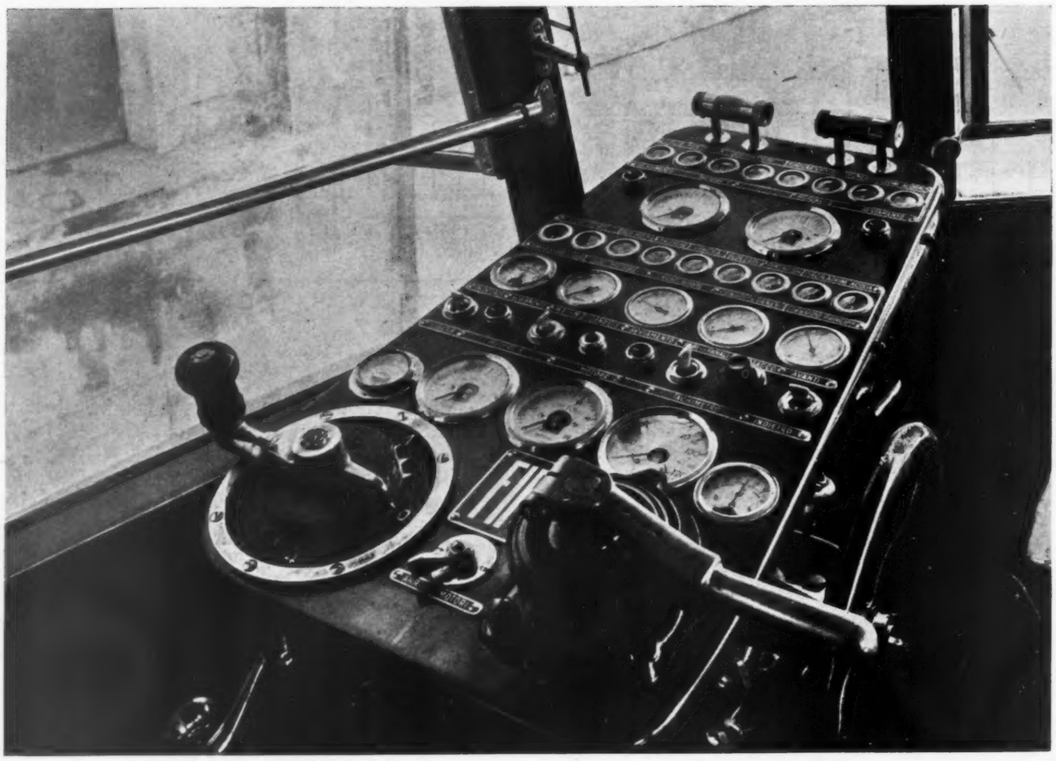
Over a period of four years the Alco 300 b.h.p. locomotives of 1931-32 operated individual averages of 5,100, 6,800, and 6,960 hr. a year at an operating and maintenance cost of $1·516, $1·367, $1·345 respectively, of which wages accounted for $0·94, $0·87, and $0·85. During the first 2½ years of its life the Alco 600-b.h.p. locomotive was in traffic at the rate of 7,165 hr. a year.

OPERATING COSTS AND HOURS OF SERVICE, DIESEL-ELECTRIC SHUNTING LOCOMOTIVES, LEHIGH VALLEY RAILROAD

Loco. No.	106	107	120	121	122	123	124	125	126	127
B.H.P.	600	600	900	900	900	900	900	900	900	900
Date placed in service	1.9.37	1.9.37	20.12.37	20.12.37	22.4.38	22.4.38	23.5.38	23.5.38	2.6.38	2.6.38
Maintenance cost, including overheads $	896·42	1,501·80	970·45	957·06	293·48	400·50	194·46	227·79	156·36	139·96
Fuel cost $	2,252·83	2,349·68	2,289·78	2,085·09	536·76	535·93	430·75	333·13	269·17	276·26
Lubricant cost $	313·46	335·85	202·64	209·88	74·52	97·38	21·28	46·91	—	—
Miscellaneous charges $	432·05	532·08	960·44	431·24	152·63	133·00	23·25	57·77	—	—
Fuel U.S. gal.	31,570	32,908	32,261	29,428	9,178	9,031	7,359	7,451	4,903	5,032
Lubricants ,,	474	513	425	440	145	205	41	95	—	—
Hours in service	7,891	7,448	5,215	5,114	1,616	1,908	1,605	1,552	1,280	1,343
Operating cost as above, $ per hr.	0·494	0·631	0·846	0·719	0·654	0·612	0·417	0·429	—	—
Allowance for driver's wages (one man), $ per hr.	0·86	0·86	0·86	0·86	0·86	0·86	0·86	0·86	—	—
Total operating and maintenance cost, $ per hr.	1·354	1·491	1·706	1·579	1·514	1·472	1·277	1·289	—	—
Approx. no. of service hours per year	6,750	6,400	6,240	6,100	3,150	3,850	3,350	3,240	3,100	3,250

All locomotives in this table have one Winton two-stroke engine. Figures are up to end of October, 1938.

Railcar Progress in Italy and Italian Africa



Driving position of double-engined Fiat diesel-mechanical railcar with multiple-unit control

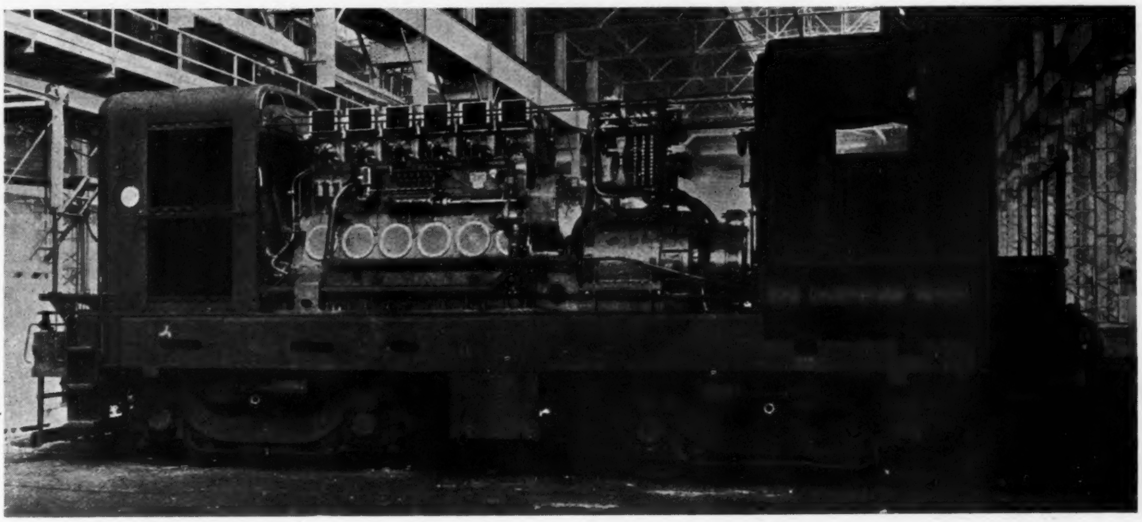
NO abatement is discernible in the rate at which new diesel railcars are built for service in Italy, Libya, Eritrea and Abyssinia, and the vehicles used are entirely of Italian manufacture. The Italian State Railways is still taking delivery of large numbers of Breda and Fiat double-engined cars of 230 to 290 b.h.p., and has extended its practice by the introduction of several cars of a different type powered by Brescia-Saurer engines. Trailer haulage is still almost non-existent on the State lines, but all the newer cars have multiple-unit control and are frequently operated in pairs by one driver, and by reason of the large number of cars at work and the manner in which they are shedded no more difficulty is caused by a sudden increase in traffic than it is with ordinary steam traction.

Within the past twelve months Fiat has delivered to the Italian State Railways 50 Littorina diesel cars each equipped with two six-cylinder 115-b.h.p. engines mounted on the bogies along with four-speed gearboxes proportioned to give a top speed of 68 m.p.h. These cars seat 56 third class passengers, and have lavatory and postal compartments, on a tare weight of 23 tons and within a length of 59 ft. The wheels are 36 in. in diameter and are spread over a bogie wheelbase of 9 ft. 3 in.; the bogie pivot is 5 ft. 7 in. behind the outer wheels, and the pivots are pitched at 39 ft. 8 in. centres. Five further cars of the same power and seating capacity are being completed at the Turin works, but as they are intended for steeply-graded lines the maximum speed is being limited to 45 m.p.h. and all four axles will be driven, contrasting with the one driving axle per bogie of the 50 cars noted above. The tare weight of the slower speed vehicles will be about 24 tons and the gross weight about 30 tons.

Other Fiat cars with multiple-unit control delivered during 1938 included three of 115 b.h.p. to the Pisa-Pontedera Railway, which seat 46 third class passengers on a tare weight of 17 tons and within a length of 51½ ft. The top speed is 45 m.p.h. In this case the wheels are only 29½ in. in diameter; on the driving bogie they are spread over a base of 9 ft. 2 in. unequally divided in relation to the pivot, and on the trailing bogie over the same base equally divided. Three double-engined 230-b.h.p. Littorinas without multiple-unit control, but with the usual two driving positions, were built for the 950-mm. gauge Arezzo-Fossato Railway. They seat 40 passengers and have lavatory, luggage, and postal accommodation within a length of 52 ft. and on a tare weight of 19 tons; the maximum permissible speed is 50 m.p.h. and the 28½-in. wheels are spread over a bogie wheelbase of 7 ft. 3 in.; the bogie centre pitch is 34 ft. 6 in. Eight similar cars carrying first, second, and third class passengers and taring 23½ tons were built for the 950-mm. gauge Libyan railways, and four 21-ton 230-b.h.p. cars with a top speed of 42 m.p.h. for the Djibouti-Addis Ababa Railway. The Libyan cars have baggage, postal, and lavatory accommodation, in addition to 12 first class and 23 second class seats and room for about 50 third class native passengers. The car body length is 72 ft. and the top speed 56 m.p.h. The metre-gauge Ethiopian railcars seat 12 first class and 16 second class passengers, with separate baggage and lavatory rooms, within a body length of 52½ ft. Both types have 28½-in. wheels.

AMERICAN OIL-ELECTRIC SHUNTER

First locomotive to this design was No. 62,000 in Baldwin's construction list



660-b.h.p. Baldwin locomotive with engine room casing removed

ONE of the lesser-known types of American diesel locomotives is the double-bogie type built by the Baldwin Locomotive Works. The basic mechanical feature of the design is the mounting of the engine, main and auxiliary generators, radiators, cooling fans, and traction motor-blower on a common subframe. This subframe is an integral steel casting mounted on bolting lugs which are a part of the main underframe, and a resilient cork-rubber composition pad is inserted between the two.

Itself an integral steel casting, the locomotive underframe incorporates a 415-gal. fuel tank, battery compartment, sandboxes, cab steps, traction motor air ducts, and housings for the drawgear and bogie centre pins. The batteries are easily accessible through trap doors, and the interiors of the compartments are protected by acid-resisting paint. The bogies also are built up on integral cast steel frames incorporating the lower portions of the traction motor air ducts. The 40-in. rolled steel wheels are spread over a base of 8 ft. and the axles are carried in Timken roller bearings. The bogies are pitched at 26 ft. centres and the length of the locomotive over coupler knuckles is 39 ft. 6 in. The truck design enables a pair of wheels to be dropped without removing the motor from the axle. The sheet steel cab is completely lined and floored with cork, and has extruded aluminium window frames. Operating alone, the locomotive can negotiate 50 ft. curves and when hauling a train, 120 ft. curves. The fully-laden weight is 95 Engl. tons and the starting tractive effort, assuming 30 per cent. adhesion, 63,600 lb. On the continuous rating of the traction motors the tractive effort at the wheel rims is 29,900 lb. at 5·7 m.p.h. The top permissible speed is 45 m.p.h.

Engine and Transmission

The De La Vergne engine has six vertical cylinders $12\frac{1}{2}$ in. diameter by $15\frac{1}{2}$ in. stroke and is set to give a top output of 660 b.h.p. at 600 r.p.m., under which conditions the m.e.p. is 80 lb. per sq. in. and the piston speed 1,485 ft. per min. A spherical combustion chamber, connected to the cylinder barrel by a throat, is incorporated in each cylinder head, and the fuel nozzle is located in the side of it. Bosch fuel injection equipment is fitted. Despite the large bore of the cylinder, only one inlet and one exhaust valve are used, and room is found for them by having the air-cell throat to one side. The piston top is dead flat. Among other unusual detail features of this engine are piston ring grooves cut in an aluminium-bronze collar cast in the aluminium piston. It is claimed that this harder alloy resists wear and prevents any distortion of the grooves. The cylinder liners are lapped into the cylinder block with a metal-to-metal fit. Engine speed is controlled by a Woodward variable-speed governor.

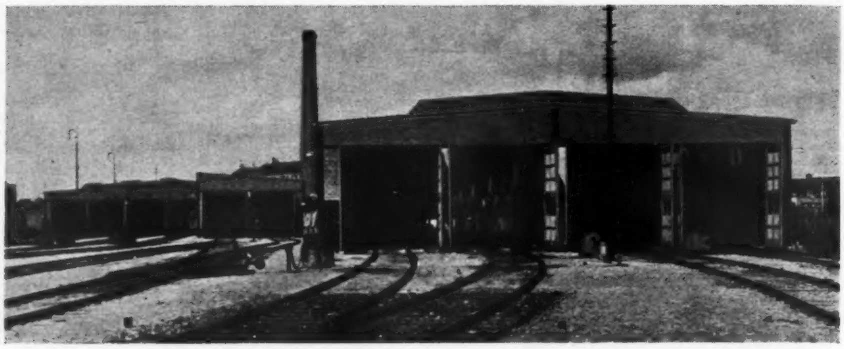
Gilled tube radiators are located at each side at the forward end of the engine hood, and cool both circulating water and engine lubricating oil. An electrically-driven fan is mounted between the two banks, and its speed can be varied by the driver. Fuel is pumped by a $\frac{1}{2}$-h.p. motor-driven pump from the main fuel tank through a filter to a 10-gal. service tank beneath the top plate of the engine hood, from which there is a gravity lead to the injection pumps. There is an emergency hand pump between the main and service tanks, and an emergency fuel cut-off valve which can be operated from the cab and from the outside of the frame.

The electrical equipment, built by Allis-Chalmers, comprises a 600-volt main generator with both self-exciting and separately-excited windings; an overhung self-excited variable-speed auxiliary generator delivering full power to the blower, fan, and compressor motors at half to full engine speed; and four force-ventilated 600-volt traction motors. The four motors are connected in parallel, and the electric control is on the Brown-Boveri servo field regulator system, which regulates the main generator excitation through the engine governor, and automatically increases the generator voltage as the motor current decreases.

A MAIN-LINE RAILCAR DEPOT

A description of a Danish shed and light-repair shop for a stud of eight high-speed trains and a dozen powerful railcars

By F. P. PEDERSEN



The express railcar shed at Copenhagen

ALL the Danish State Railways Lyntog (Lightning trains) and a number of the single-unit diesel railcars are concentrated at Copenhagen. For these a new shed has been erected in the north-eastern part of the city about 3½ miles from the Central station in a yard for empty passenger stock. Originally it was the intention to build a shed for steam locomotives on this site, but with the ever-growing use of diesel railcars and the introduction of three-car and four-car Lyntog it became necessary to construct a diesel depot instead, and fit it out in an up-to-date manner.

From the accompanying ground plan it will be seen that the shed has 10 tracks, of which four can hold three single-unit double bogie diesel cars or a three-car Lyntog, while the remaining six tracks each can hold four single-unit railcars or a four-car Lyntog. The whole depot has stabling accommodation for 36 cars of 20 m. (66 ft.) length each. The shed was built in two parts, and between the construction of the two sections there was an interval of some years. The proportions and layout were limited to some extent by the shape and size of the available site. Adjacent there is a building containing resting and sleeping rooms for drivers.

The shed covers an area of 5,200 sq. m. (56,000 sq. ft.) and is divided in two halls with a low building between and low side buildings. In these buildings are offices, shops, stores of spare parts and lubricating oil, sand and grease. There is also a depot for the International Sleeping Car Company, which runs the restaurants in the Lyntog, and sleeping, resting, washing, and bathing rooms for the driving and shed staff.

Shed Construction

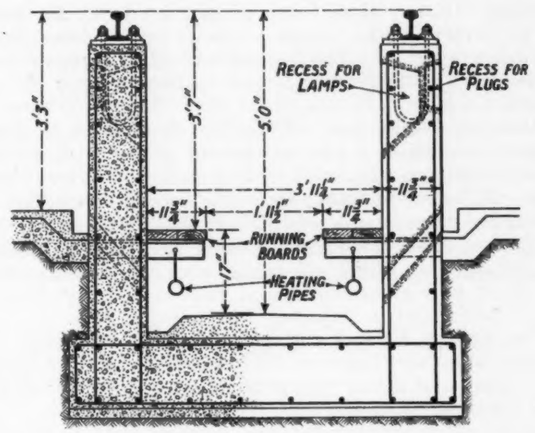
The shed is a steel-framed, brick-filled building with a timber roof. Above the tracks, the underside of the roof is covered with asbestos-cement lining. The roof lights can be opened and closed from the floor. To prevent the exhaust from the diesel engines filling the shed when the engines are starting or being tried, there are telescopic chimney pipes at various points above the pits; these pipes can be lowered over the exhaust outlets in the roofs of the cars, so that the exhaust is led direct into the open air. All roofs and walls in the shed are painted white, and the offices and staff rooms are in bright colours. In all the buildings there is ample natural and artificial light.

The shed floors are of concrete and, as may be seen from the cross-section, the tracks are placed on reinforced-concrete walls between which is an inspection pit 1·53 m. (5 ft.) deep so that it is possible to walk upright under the cars. The rails rest on cast iron soleplates, as shown, or on longitudinal timbers. At a depth of 1·10 m. (3 ft. 7 in.) below rail level, running planks are placed

Interior of the Danish State Railways' diesel shed showing the construction of the pits with dropped floor between so that equipment on the outside of the vehicles and below the floor level, can be inspected and adjusted easily

along the walls, and standing on these it is easy to reach the apparatus placed on the underside of the cars. Beneath the running planks are located the heating pipes. In the side walls are numerous recesses housing electric lights for use in the inspection of the cars, which work usually takes place during the night. These recesses also contain plugs for connecting the train brakes with a pipe for testing purposes and for cleaning by air blast the generators and traction motors.

Between each pair of tracks the floor lies 1·0 m. (3 ft. 3 in.) below rail level by which the best conditions for inspection of the bogies and underframes are obtained. Ladders on rubber-tyred wheels are used for cleaning the outsides of the windows and of the car walls; a cleaner can thus work at the most suitable height and pull the ladder and himself along. The shed is heated from a central heating plant, from which the hot water pipes are led in ducts to the different places. By locating the shed heating pipes in the pits, warm air is caused to circulate round the undersides of the cars, which in winter may often be wet or even snow-covered. The fuel oil is supplied outside the shed, just east of which are three underground tanks containing 7,700 gal. each, and from these the fuel oil is forced through pipe lines by electrically-driven pumps to standards placed between the tracks, where each delivery of fuel is automatically measured.



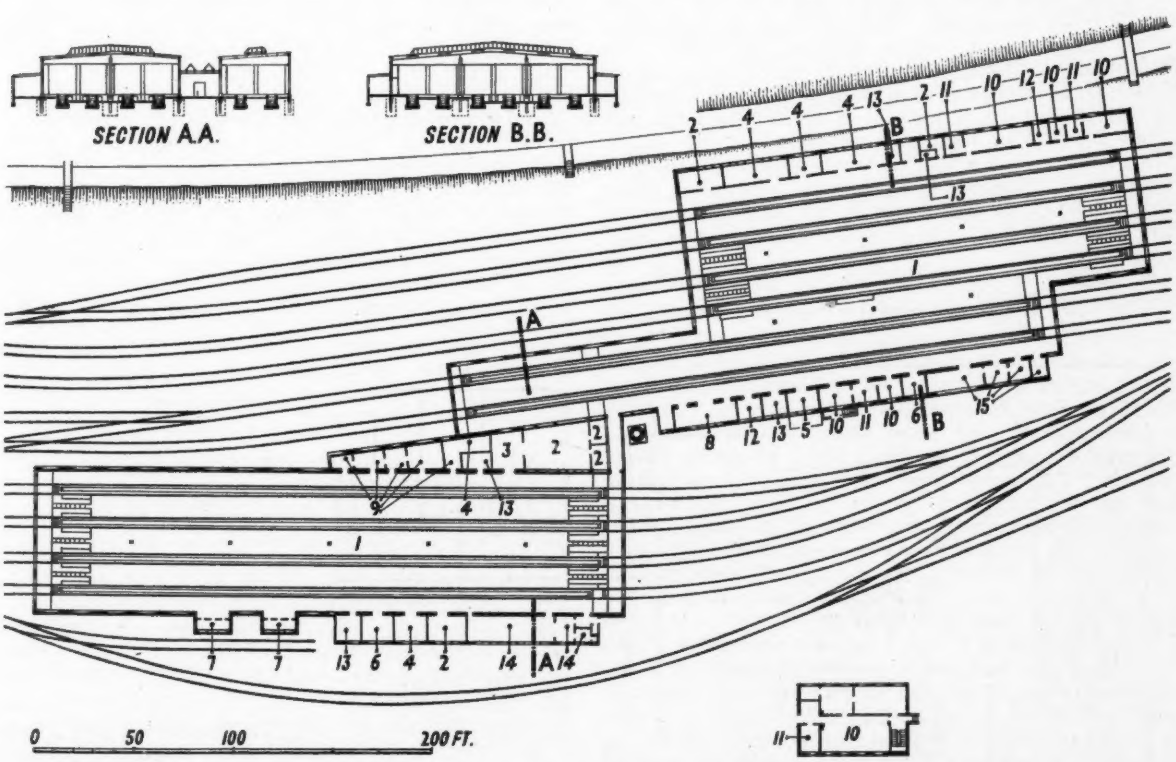
Cross section of the inspection pits showing wooden running boards for use of the workmen, and the dropped floor on the outside

Stock and Maintenance Details

The present diesel stock at the depôt comprises four three-car 1,100-b.h.p. Lyntogs, four four-car Lyntogs, and 12 diesel-electric single-unit double-bogie 550-b.h.p. cars of the MO type. The eight Lyntogs cover an approximate aggregate distance of 1,835,000 km. (1,140,000 miles) a year, and the MO cars about 1,500,000 km. (935,000 miles). The consumption of fuel oil is about 4,000,000 litres (880,000 gal.) a year, of lubricating oil about 75,000 litres a year, and of braking sand 110 cu. m. (3,900 cu. ft.). Most of the train-sets and railcars are at work all day and return to the shed during the evening.

The staff comprises 38 skilled fitters and electricians and 55 labourers (oilers and cleaners) for cleaning the trains and cars. The running staff comprises 54 drivers and assistant drivers. Drivers stationed at other depôts who on certain rosters have to spend the night in Copenhagen, are accommodated in eight single bedrooms in a building adjoining the shed.

Daily, fortnightly, and monthly inspections are carried out at the depôt, light repairs are effected, and worn parts



Plan and sections of depot at Copenhagen with accommodation equivalent to 36 single-unit 66-ft. railcars

replaced. Heavy repairs and general overhauls are done at the central works, where a special railcar department has been organised. The inspections and light repairs are done to a definite programme, which mainly is as follows:—

Daily: Inspection and performance observation of diesel engines, and testing and adjustment of the brakes (the Lyntogs are provided with drum brakes and electro-magnetic rail brakes, and not a little of the general maintenance work has been connected with brake adjustments; the single-unit diesel cars have the usual block brakes); filling of fuel and lubricating oil tanks; cleaning of lubricating oil filters and adjustment when necessary; inspection of electrical apparatus, including the lighting system.

Fortnightly: All fuel valves are cleaned and tested; all electric apparatus inspected and cleaned, particular attention being paid to the commutators and brush gear; cleaning by air blast of the main generators and the traction motors; topping up and adjusting the battery; cleaning and adjustment of the air filters and fuel oil filters; overhaul of the brake apparatus and rigging; general inspection of the bogies, buffers, and lower mechanical portion; topping up the lubricating grease for the nose-suspended traction motor gears.

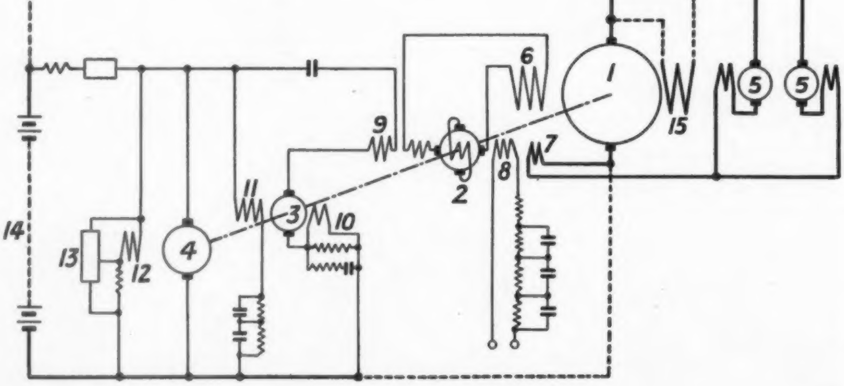
Monthly: All the grease-lubricated bearings in the electrical apparatus are refilled and the brake compressors and brake gear lubricated. The electric controller and relays are cleaned and checked over. After 40,000 km. (25,000 miles) the cylinder heads are taken off and the engine partially opened up in order to inspect, clean, and bring up to scratch the inlet and exhaust valves; the pistons and piston rings are cleaned and inspected and the scraper rings are sharpened; the big end and gudgeon pin bearings are inspected. Every 150,000-200,000 km. (93,000 to 124,000 miles) a heavy repair is scheduled. During 1938 the three-car Lyntogs, which are the oldest, and which had by that time run from 500,000 to 700,000 km. (310,000 to 435,000 miles) each, had their crankshafts taken out for inspection for the first time, and one or two of the main bearings were replaced by new ones. But generally speaking the engines of these trains, set to work in 1935, still have the original pistons and cylinder liners.

METADYNE TRANSMISSION PROPOSALS

IN the application of the diesel engine to traction in conjunction with electric transmission, it is necessary to control automatically the excitation of the main generator so as to maintain the engine load constant. One well-known principle on which this may be done is to provide an exciter to control the generator field-strength, the exciter supplying a voltage which varies very steeply with change of engine speed, so as to raise the load when the engine speed tends to increase and to reduce the load when it tends to decrease. In a paper on the applications of the metadyne to railway traction, read before the Institution of Electrical Engineers on February 23 by Messrs. G. H. Fletcher and A. Tustin, of the Metropolitan-Vickers Electrical Co. Ltd., it is claimed that for such duties it might be used with advantage as the exciter, introducing a field-forcing action which tends to overcome the inductance of the generator field and to ensure that it follows the indications of the tachometer exciter with very little lag. The following information is taken from that paper.

A diagram of connections for the transmission of a proposed oil-electric shunting locomotive employing the metadyne as an exciter in this way is shown in Fig. 1. On the same shaft as the main generator are mounted a metadyne exciter and two other small dynamos. One of these, *DY*, is maintained at a constant voltage by a voltage regulator, and keeps charged the battery that is used for starting the engine and for the auxiliary current supply. The second small dynamo is analogous to the regulator dynamo on the metadyne transformers, except that its back e.m.f. is opposed to the constant voltage of dynamo *DY* instead of to the voltage of the line. It has a reversed series winding to increase the change of current resulting from a given change in speed.

The winding of the exciter metadyne which is supplied in series with this regulator machine is, in this case, a variator winding. The exciter metadyne acts as a relay, and when, for example, the current in this variator winding increases, the exciter metadyne applies a very high voltage to the generator main field until the current is brought back to normal, a field forcing action being obtained to overcome the inductance of the generator field. The whole arrangement ensures that the generator voltage is automatically and rapidly adjusted to prevent any



1.—Main generator.
2.—Metadyne exciter.
3.—Regulator dynamo.
4.—Dynamo for battery charging.
5.—Traction motors.
6.—Main field of generator.
7.—Series field of metadyne exciter fed with main generator current.
8.—Separately excited field of metadyne exciter.
9.—Regulating field of metadyne exciter.
10.—Reversed series winding of regulator dynamo.
11.—Separate excitation of regulator dynamo.
12.—Field winding of supply dynamo
13.—Voltage regulator.
14.—Battery.
15.—Starting field of main generator.

Fig. 1. Metadyne control arrangement for proposed oil-electric shunting locomotive

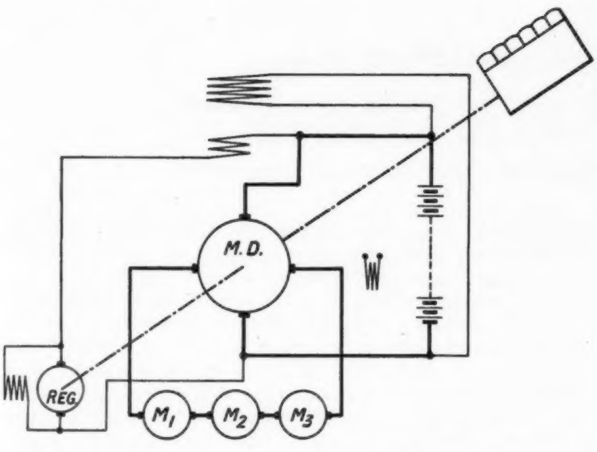


Fig. 2—Metadyne control scheme for three-power oil-electric-battery locomotive

change in speed, *i.e.*, adjusted to the output of the engine and so as to maintain the speed constant. A special series winding is provided on the main generator, which is used in starting the engine from the battery.

Diesel-Electric-Battery Locomotives

On services in which a limited amount of running is required away from the overhead line, particularly for yard shunting where it would be uneconomical to provide overhead line for all the sidings, the useful diesel-electric-battery type of locomotive* could be provided, for which a generator of the metadyne type serves very well.

It was found in one application which has been investigated that although the maximum duty of the locomotive required 150 h.p. at the wheels, the average load for the whole day was not more than about 15 h.p. This means, of course, that for an ordinary diesel locomotive a 150-b.h.p. engine would have to be supplied to take care of the peak load, which is only on for very short periods. If some way could be found of providing this peak load for a short period, an engine of about 20 b.h.p. would be ample. A scheme which can be used to this end is shown in Fig. 2. The metadyne is mechanically coupled to the diesel engine, the primary being connected across the battery and the secondary connected to the traction motors. In this case the regulator dynamo controls a primary variator winding and causes the primary current to increase or decrease according to the amount by which the speed falls slightly below or rises slightly above normal. Thus the speed is kept nearly constant, whatever the motor demand or even if the motors regenerate, the balance of load being supplied or absorbed by the battery.

The operation would be that with the locomotive stationary the full output of the metadyne would be used in charging the battery. When the energy required by the motors exceeded the value corresponding to the maximum torque of the engine, the battery would automatically operate in parallel with the engine, and supply the extra power through the metadyne to the traction motors. This would be done quite independently of the driver, who would not need to think about anything more than moving his controller to give the required speeds, the metadyne taking power from the battery quite automatically. As the battery discharge would only be required for short periods, a comparatively small battery would serve the purpose.

An additional advantage is that with a battery of a type such as would accept heavy charging rates, the scheme would permit of regenerative operation, and all braking would be done regeneratively. It would therefore be possible to reduce the amount of use made of air brakes, and the adoption of regenerative braking would reduce slightly the size of diesel engine required. In certain cases, if the engine failed the battery could be used to operate the locomotive for limited service.

* See article on operation of the New York Central three-power locomotives in issue of this Supplement for February 23, 1934.

Fire!

DESPITE careful precautions, diesel locomotives, and railcars are as yet by no means immune from fires, and in two recent conflagrations the spread has been so rapid that the ordinary fire-extinguishing apparatus has been of no use whatever. The cause of a fire often has nothing to do with the fuel, although it had in the case of the fire on the first Santa Fé 3,600-b.h.p. locomotive in 1936, and, once the fire is started the presence of fuel has no effect one way or the other. We remember an instance in which a finished railcar caught fire in the maker's works through carelessness after the interior had been cleaned up, using turpentine and other inflammable material. In two minutes the upper part of the car was destroyed and the works roof was alight; in ten minutes the car was practically gutted, but the fuel oil which was in the tank did not catch fire.

At the end of January one of the 480-b.h.p. Ganz twin-car diesel-mechanical trains belonging to the Uruguay State Railways and hired out to the Central Uruguay Railway (for description see issue of this Supplement for October 28, 1938) caught fire near Montevideo, and all the luggage and mails were destroyed; the passengers had narrow escapes, and the high wind which was blowing assisted in gutting the train in a short time.

On December 19 last the Danish State Railways' Lyntog train operating the Kronjyden service caught fire while travelling at speed near Hobro, in North Jutland. The fire started over one of the traction motor articulation bogies and in the course of an hour or two completely gutted the passenger compartments of all three coaches. The train was stopped quickly by application of the emergency brake, and no one was hurt and no luggage lost. The fire could not be extinguished by the appliances on the train, and the local fire brigades could not get to the train because the roads were practically impassable with snow. It was believed at first that the cause of the fire was blocking of the traction motor ventilation intakes by snow, resulting in overheating and short-circuits caused by the melted snow in the motors, as trouble of this nature had been experienced before. All the remaining Lyntog trains with the exception of those working the Englanderen services in connection with the Esbjerg—Harwich boats were temporarily withdrawn from service and new ventilation intakes on the roofs fitted; in the meantime they were replaced by steam trains, the services being combined as far as practicable to reduce the number of trains required. Later investigation of the burnt-out train made it doubtful whether the cause of the fire was as first believed, or whether it was simply a partial short-circuit in the cables between the coaches. The two engine compartments were practically undamaged, thanks to the steel partitions separating them from the remainder of the train, and the same applied to the bogies, but the three steel coach bodies were buckled so badly as to be entirely useless. The cost of the damage is estimated at about Kr. 300,000.

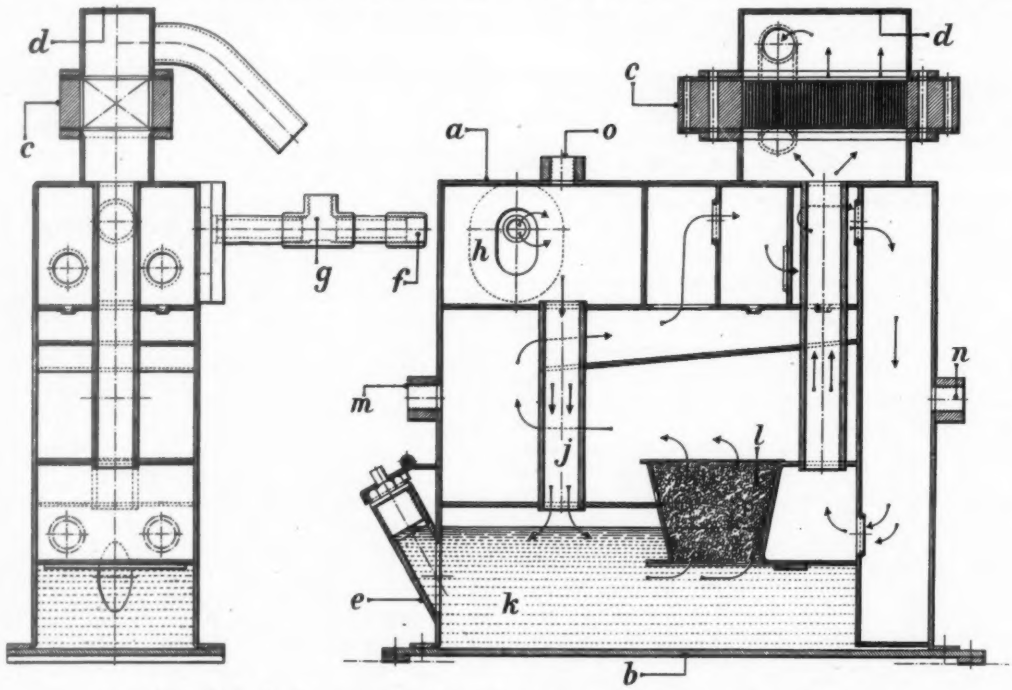
FLAME-PROOF DIESEL LOCOMOTIVES

New exhaust conditioner, stopping the most penetrating types of flame, forms first big step towards making sub-surface locomotives flame-proof up to the standard of existing regulations for electrical equipment

DESPITE the number of diesel locomotives which have been built for operation in dangerous areas during the past twelve months, and which generally have been considered to have had flame-proof equipment, the precautions taken by no means comply with what the Mines Department, for example, regard as flame-proof. This subject is becoming of increasing importance, because of the widening application of diesel locomotives in gaseous and non-gaseous mines and in inflammable atmospheres, and as we indicated in the issue of this Supplement for August, 1937, it is closely bound up with the actual condition of the oil engine.

To meet the requirements of the Mines Department, the Hunslet Engine Co. Ltd. has gone thoroughly into the question of absolutely flame-proof equipment for diesel locomotives, and, as the first main step, has completely revised the design of its exhaust-gas conditioner as illustrated and described in the issue of this Supplement for October 29, 1937. A section through the latest type is shown on this page, and, fitted to a specially-designed Gardner two-cylinder oil engine, it has been tested in a comprehensive manner at the Buxton testing station of the Mines Department.

The new exhaust-gas conditioner is constructed in a rectangular chamber *a* in ¼-in. mild steel plate with a base *b* of ⅜-in. steel plate, which forms a cover bolted to external flanges. The spark arrestor or plate protective device is at *c*, and consists of a packet of 73 stainless steel plates, each 2¼ in. long, 2 in. deep, and 0·099 in. thick at the ends and thinner in the middle. Each plate is machined on both sides over a width of 2 in., leaving ⅛ in. at each end of the nominal thickness of 0·099 in. These plates are assembled within a rectangular frame solid at the sides and at one end, and with a clamping cover at the other end, forming a grille having an assembly of vertical gaps, each being 2 in. long, 2 in. deep, and 0·016 in. wide. A fabricated cap *d* is fitted over the outlet side of the grille to lead the exhaust to the exhaust pipe. Water is introduced to the bottom compartment of the main chamber through an orifice *e* and rises to the level shown. Exhaust gases enter through the inlet pipe *f*, and for test purposes a tee piece *g* was inserted so that a sparking plug could be fitted to ignite an explosive mixture.



A section through the new Hunslet exhaust-gas conditioner and spark arrestor

The gases first enter the compartment *h* and pass down the vertical pipe *j* to the water chamber *k*. The water in this chamber materially assists in extinguishing any flame, but is provided primarily to wash the gases and remove the smell incidental to the exhaust of the ordinary diesel engine. The gases then pass through a compartment *l*, which has expanded-metal grids at top and bottom for the purposes of retaining a packet of metal turnings; these turnings are intended to act as a flame trap. The gases then pass through a system of baffles, and finally discharge through the spark arrestor *c*. Welded bosses *m* and *n* for the attachment of pressure recorders were attached for the tests. A fuel injector of the type used on diesel engines was fitted at *o* so that unburnt fuel oil could be injected into the conditioner.

AMERICAN DIESEL-ELECTRIC STREAMLINERS

An account of the present position and of the most recent additions

(By our American special correspondent)

THE rise in popularity of the diesel-electric streamlined train in the United States has been remarkable, and in the space of five years this new type of passenger motive power has superseded many steam locomotives and has taken on the operation of schedules which could not be performed with the old motive power. The usual limitations of curves and grades or light rails have not seriously affected this new type of motive power. Some improvements to road bed have been necessary to ensure safe operation at the greatly increased running speeds, but the lower axle load and the lower centre of gravity of the new vehicle, and furthermore, the absence of shock and strain because of the smooth electric drive minimise the destructive action on the track and likewise permit safe and comfortable operation at the high speeds now common on many roads.

The accompanying table prepared for a quick survey of the diesel-electric streamliners now in service shows a total of 50 streamliners including spares, with a grand total of more than 110,000 b.h.p. Perhaps the most conspicuous factor in this development has been the universal acceptance of electric drive. This feature, contributing both to easy handling and the maximum utilisation of the diesel engine, is recognised in America as an indispensable element in the enviable record of these several fleets of super-speed passenger carriers.

New 7,800-b.h.p. Triple-Unit Locomotive

The Seaboard Railway inaugurated about the middle of December two diesel-electric-hauled Pullman trains each way daily between New York and Miami on the East coast and St. Petersburg on the West coast of Florida. These trains, called the Orange Blossom Special, are making the trip to Miami, 1,387 miles, in 26 hr. 25 min. and to St. Petersburg in 27 hr. The train of through cars is handled over the electrified Pennsylvania Railroad to Washington, thence with diesel-electric locomotives over the Richmond, Fredricksburg, & Potomac Railroad to Richmond, and then by the Seaboard Railway to the Florida points. The cars are standard completely air-conditioned Pullman equipment with coaches, diner, sleeping cars, and lounge-recreation car.

The motive power for these trains includes six A units and three B units. Each unit carries two 1,000-b.h.p. diesel-electric generating sets and each of the three-cab locomotives is made up of two A and one B unit. The engineer operates the three-coupled units from a single control station in the leading cab. Movements of the control handle are electrically relayed to each of the six engines, thus actuating the engine governors to regulate the speed and power output of each engine-generator set. The running gear and cabs are similar to that of the 5,400-b.h.p. three-cab locomotives purchased last year by the Union Pacific for western trans-continental service. Each three-axle truck carries two axle-mounted traction motors on the outside axles. The cab is carried on centre-pins located at the centre of each truck frame. The triple-unit locomotives are the first big American diesel locomotives to have a driving position at each end. Three 600-b.h.p. Winton two-stroke engines and attached generators are used to provide power for the numerous train auxiliaries, and raise the total installed output to 7,800 b.h.p.

Instead of the 900-b.h.p. 12-cylinder 8 in. × 10 in. two-stroke Winton engines used by the Union Pacific, however, the Seaboard locomotives are powered by the new 1,000-b.h.p. engines of the two-stroke 12-cylinder vee type with 8½-in. bore and 10-in. stroke. Each three-cab loco-

The Orange Blossom Special, headed by a triple-unit locomotive, on its inaugural run

Diesel-Electric Passenger Train Equipment in Service in the United States

Railroad	No. of Trains	Name of Train	Cities Served	Wt. of Trailing Train: Light	Wt. of Trailing Train: Loaded*	No. of Cars	Car Builder	No. of Locos.	Wheel Arrangement	Traction h.p. per Loco.	Loco. Builder	Total wt., short tons	Elec. Eqpt. Builder	Eng. Builder	No. and b.h.p. of engines	Date in service
Alton R.R. ..	1	Abraham Lincoln	Chicago-St. Louis..	390	414	8	A.C.F.	1	B-B	1,800	GE	126	GE	EMCO	2–900	July, 1935
A.T. & S.F. Ry. ..	1	Super Chief ..	Chicago-Los Angeles	425	452	9	Budd	1	2(A1A-A1A)	3,600	EMCO	284	GE	EMCO	4–900	June, 1937
	1	,, ,, ..	,, ,, ,,	518	545	9	Pull-Stand.	1	2(A1A-A1A)	3,600	EMCO	284	GE	EMCO	4–900	Feb., 1938
	2	El Capitan ..	,, ,, ,,	252	267	5	Budd	2	A1A-A1A	1,800	EMCO	147	GE	EMCO	2–900	Feb., 1938
	1	San Diegan ..	Los Ang.-S. Diego	252	267	5	Budd	1	A1A-A1A	1,800	EMCO	147	GE	EMCO	2–900	Mar., 1938
	1	Kansas Cityan ..	Chicago-Wichita	353	374	7	Budd	1	A1A-A1A	1,800	EMCO	147	GE	EMCO	2–900	Apr., 1938
	1	Chicagoan ..	Wichita- Chicago	353	374	7	Budd	1	A1A-A1A	1,800	EMCO	147	GE	EMCO	2–900	Apr., 1938
Baltimore & Ohio R.R.	2	Royal Blue Columbian	Washington-New York	390	414	8	Pull-Stand.	2	2(A1A-A1A)	3,600	EMCO	285	W. Co.	EMCO	4–900	June, 1937
	4	Capitol Ltd. National Ltd.	Washington-Chicago	720	750	9.	Pull-Stand.	4	2(A1A-A1A)	3,600	EMCO	285	W. Co.	EMCO	4–900	Feb., Mar., 1938
Boston & Maine R.R.	1	Flying Yankee ..	Boston-Bangor ..	108	118	3	Budd	—	—	—	—	—	GE	EMCO	1–600	Feb., 1935
C.B. & Q. R.R. ..	1	Pioneer Zephyr ..	Kansas City-Lincoln	144	156	4	Budd	—	—	—	—	—	GE	EMCO	1–600	Mar., 1934
	1	Sam Houston ..	Houston-Ft. Worth	113	121	3	Budd	—	—	—	—	—	GE	EMCO	1–600	Apr., 1935
	1	Mark Twain ..	St. Louis-Burl'ton	144	156	4	Budd	—	—	—	—	—	GE	EMCO	1–600	Oct., 1935
	1	Ozark State Ltd.	St. Louis-Kansas Cy	113	121		Budd	—	—	—	—	—	GE	EMCO	1–600	Apr., 1935
	2	Denver Zephyrs	Chicago-Denver ..	416	446	10	Budd	2	2(B-B)	3,000	EMCO	213	GE	EMCO	2–900 1–1,200	Oct., 1936
	2	Twin Zephyrs ..	Chicago-Minneap.	254	275	7	Budd	2	B-B	1,800	EMCO	121	GE	EMCO	2–900	Dec., 1936
	1	Ozark-State Zephyr	Kansas City-St. Louis	99	111	4	Budd	—	—	—	—	—	EMCO	EMCO	2–1,000	Jan., 1939
C.R.I. & Pacific Ry.	1	Texas Rocket ..	Houston-Ft. Worth	131	140	3	Budd	1	B-B	1,200	EMCO	114	GE	EMCO	1–1,200	Sept., 1937
	2	Rocket	Kansas Cy-Minneap.	131	140	3	Budd	1	B-B	1,200	EMCO	114	GE	EMCO	1–1,200	Sept., 1937
	1	,, ...	Kansas Cy-Dallas..	131	140	3	Budd	1	B-B	1,200	EMCO	114	GE	EMCO	1–1,200	Sept., 1937
	1	,, ...	Chicago-Peoria ..	165	177	4	Budd	1	B-B	1,200	EMCO	114	GE	EMCO	1–1,200	Aug., 1937
	1	,, ...	Chicago-Des Moines	165	177	4	Budd	1	B-B	1,200	EMCO	114	GE	EMCO	1–1,200	Aug., 1937
G.M. & N. R.R. ..	2	Rebel	Jackson-New Orl.	229	241	4	A.C.F.	—	—	—	—	—	W. Co.	ALCO	1–660	July, 1935
	1	,, ...	Mobile-Union ..	137	146	2	A.C.F.	—	—	—	—	—	W. Co.	ALCO	1–660	Jan., 1938
Illinois Central R.R.	1	Green Diamond ..	Chicago-St. Louis..	238	253	5	Pull-Stand.	—	—	—	—	—	GE	EMCO	1–1200	May, 1936
N.Y.,N.H.& H. R.R.	1	Comet	Boston-Providence	127	136	3	Goodyear-Zep.	—	—	—	—	—	W. Co.	W. Co.	2–400	June, 1935
Seaboard Railway..	2	No. 21-22 ..	Rutherfordton-Hamlet	78	93	1	St. L. Car	—	—	—	—	—	GE	EMCO	1–600	Feb., 1936
	1	Silver Meteor ..	New York-Florida	405	426	7	Budd	1	A1A-A1A	2,000	EMCO	147	EMCO	EMCO	2–1,000	Feb., 1939
	3	Orange Blossom	New York-Florida	760	799	13	Pull-Stand.	3	3(A1A-A1A)	6,000	EMCO	450	EMCO	EMCO	6–1,000	Dec., 1938
Southern Ry. ..	6	—	Chattanooga-Birmingham	90	102·5§	6	St. L. Car	—	—	—	—	—	W. Co.	Fbks.-Morse	1–750 (Date	Oct., 1938 ordered)
Union Pacific R.R.	1	City of Salina ..	Kansas City-Salina	116	125	3	Pull-Stand.	—	—	—	—	—	GE-W	Winton	1–600	Feb., 1934
	1	City of Portland..	Chicago-Portland	308	329	7	Pull-Stand.	—	—	—	—	—	GE	EMCO	1–1,200	Oct., 1934
	1	‡City of Los Angeles (first)	Chicago-Los Ang.	318	345	9†	Pull-Stand.	1	2(B-B)	2,100	EMCO	185	GE	EMCO	1–900 1–1,200	Apr., 1936
	1	‡City of San Francisco (first)	Chicago-San Francisco	318	345	9	Pull-Stand.	1	2(B-B)	2,400	EMCO	215	GE	EMCO	2–1,200	May, 1936
	1	‡City of Los Angeles (second)	Chicago-Los Ang.	818	857	14	Pull-Stand.	1	3(A1A-A1A)	5,400	EMCO	438	GE	EMCO	6–900	Dec., 1937
	1	‡City of San Francisco (second)	Chicago-San Francisco	818	857	14	Pull-Stand.	1	3(A1A-A1A)	5,400	EMCO	438	W. Co.	EMCO	6–900	Dec., 1937
	2	City of Denver ..	Chicago-Denver ..	452	482	10	Pull-Stand.	2	2(B-B)	2,400	EMCO	215	GE	EMCO	2–1,200	June, 1936

* Estimated 3 tons per car loading
† Chair car and room sleeper added August, 1938
‡ Standard equipment rebuilt in Company shops
§ Weight of power car only. Each power car carries mail and baggage and hauls one trailing coach

EMCO Engines, 600, 900, and 1,200 h.p.—8, 12, and 16—8 × 10 cylinders—2 cycle—750 r.p.m.
EMCO Engines, 1,000 h.p.—12—8½ × 10 cylinders—2 cycle—800 r.p.m.
ALCO Engines, 660 h.p.—6—12½ × 13 cylinders—4 cycle—750 r.p.m.

Westinghouse Co. Engines, 400 h.p.—6—9 × 12 cylinders—4 cycle—900 r.p.m.
Winton Distillate, 600 h.p.—12—7½ × 8½ cylinders, 4 cycle, 1,200 r.p.m.
Fairbanks-Morse, 750 h.p.—5—8 × 10 × 10 cylinders—2 cycle (opposed pistons)—720 r.p.m.

motive is 210 ft. long and weighs 900,000 lb. Each 2,000-b.h.p. cab has a tank capacity of 1,200 U.S. gal. of diesel fuel and 1,100 U.S. gal. of water for engine cooling and train heating. Fuelling stops are made at Hamlet, N.C. and at Wildwood, Florida. The run from Richmond to Miami is 1,046 miles, from Richmond to Washington 116½ miles, and from New York to Washington 225 miles. Some of these locomotive units, operating as 4,000-b.h.p. sets, were run-in on the Southern State Limited before going on to the Orange Blossom Special.

The Silver Meteor

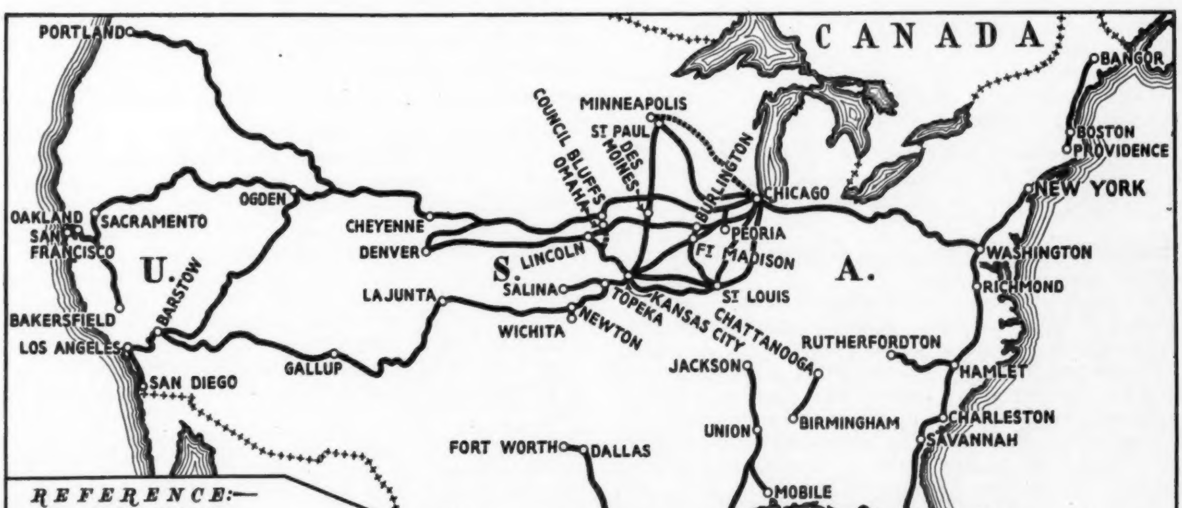
Recently published timetables forecast the inauguration of the first all-streamlined passenger train in the U.S. North-South service. The Seaboard Railway (formerly Seaboard Air Line Railway) initiated this service on February 2 with a stainless steel coach train of seven cars named the Silver Meteor. This train provides a fast one-night-out service for coach passengers between Washington and Florida points. The power unit is a single-cab 2,000-b.h.p. diesel-electric unit, duplicate of the A units now hauling the Orange Blossom Special.

Built of stainless steel by the E. G. Budd Manufacturing Company, of Philadelphia, this train provides unusual comfort and accommodation at coach fares, which are now 1½ cents (or approximately ¾d.) a mile. It runs alternately to the east and west coasts of Florida every three days, serving Savannah, Jacksonville, West Palm Beach, Miami, Tampa, St. Petersburg, and other Florida cities, and is to be an all-the-year-round train. All seats in the train will be reserved without additional fee, and all accommodation must be booked in advance.

The new train is booked to leave the Pennsylvania terminal in New York City at 3.30 p.m., enabling passengers from north of that city to make convenient connection with it, and it runs *via* Philadelphia, Baltimore, and Washington to Norfolk, and thence as for the Orange Blossom Special. As with that train, it is hauled between New York and Washington by a Pennsylvania electric locomotive. The travelling time between New York and Miami is 26½ hr. southbound and 27 hr. northbound.

The train comprises seven cars, including a dining car, tavern car, and observation car, all of new design and completely air-conditioned. There are 280 revenue seats plus 120 non-revenue seats, and the use of adjustable reclining chair seats provides each passenger with comfortable day and night accommodation; pillows are available at night. Each coach has roomy dressing-smoking rooms for men and women, and lavatory and washing rooms. Meals at moderate prices are served in the dining car, breakfast costing 50 to 65 cents (2s. to 2s. 6d.) and lunch or dinner 60 to 75 cents (say 2s. 6d. to 3s.); there is also an inexpensive *a la carte* service. Light refreshments and soft drinks—and in the States permitting them, wines and liquors also—are obtainable in the tavern car. A registered nurse-stewardess is carried to assist with children and invalids.

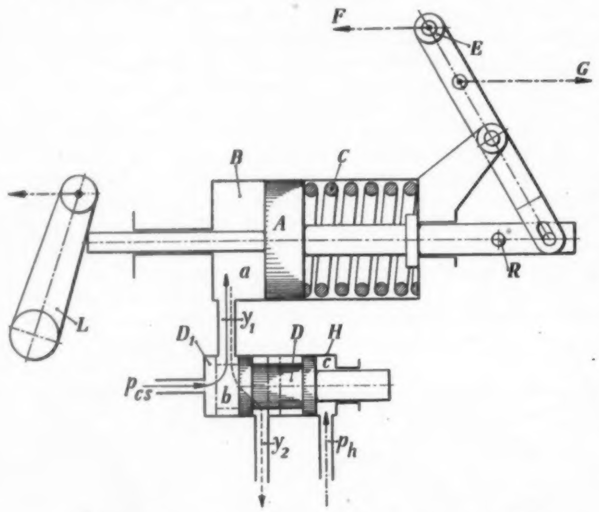
One of the most notable of recent events in the American railway world is the order placed by the Chicago & North Western Railroad for two lightweight streamlined diesel-electric trains for operating the celebrated " 400 " service between Chicago and the Twin Cities, which has hitherto been worked by steam traction with big six-coupled locomotives. The two diesel-electric locomotives are being built by the Electro-Motive Corporation at a price of $720,000, and each will be powered by four 12-cylinder vee two-stroke Winton engines. Two driving positions are to be incorporated in each twin-unit locomotive so that it can be attached, without turning, to the North Western Limited, which leaves each terminal immediately after the arrival of the 400. Each locomotive thus makes one return trip daily between Chicago and Minneapolis, a total distance of 850 miles. A total of 20 coaches has been ordered from the Pullman-Standard Car Manufacturing Company for the new 400 service at a cost of $1,600,000. The capacity of each train will be 409 seats, including 56 seats in the diner and 36 in the taproom-lounge, but excluding seats in the smoking rooms.



Map showing lines over which high-speed diesel services are in operation in the United States

An Automatic Engine Stopping Device

THE great majority of diesel railcar and locomotive installations now incorporate one device or another for automatically shutting down the engine if there is any drop in pressure in the lubricating oil system, and of giving some type of visual indication on the driving dashboard. The arrangement used by Ganz is shown in the accompanying illustration. The device is fixed on the cover of the fuel injection pump regulating levers and, as shown diagrammatically, comprises the stopping cylinder *B* and the differential cylinder *H*. In the first cylinder is housed the stopping piston *A*, loaded by spring *C*; the rod of piston *A* acts directly on the lever *L*, which controls the regulating wedges of the fuel pump. Cylinder *H* contains the differential piston *D*; the space *b* of this cylinder is connected to certain of the main bearings of the engine through *pcs*, and by means of y_1, to space *a* of the stopping cylinder *B*. The space *c* of the differential



Diagrammatic representation of the method used by Ganz to shut down an engine in case of failure in the lubricating oil supply

cylinder is connected to the piping between the lubricating oil pump and the oil cooler.

The ratio of the lubricating oil pressure *pb* in the bearings to that of *pc* before the cooler is approximately constant at different speeds and lubricating oil temperatures. According to this constant value the sectional areas of the differential piston are determined in a manner such that under normal conditions the piston *D* is in the position shown by the full lines in the diagram. The lubricating oil pressure in the bearings acts against spring *C*, and as long as this pressure is greater than 1 kg. per sq. cm. (14 lb. per sq. in.) the piston *A* is kept in the right-hand position, as indicated in the illustration.

If there should be a failure of the lubricating oil circuit owing to the fracture or cracking of a pipe, or to a failure of the lubricating oil pump, the pressure *pb* falls below 1 kg. per sq. cm., and spring *C* moves piston *A* to the left and displaces, by means of lever *L*, the regulating wedges into the position corresponding to zero delivery. If one of the main bearings should seize, the ratio between *pb* and *pc* is altered, that is, it becomes higher than the normal value. The equilibrium of the differential piston is thus disturbed, and the piston is moved in the direction of pressure *pc* (to the left in the diagram) to position D_1, marked by chain-dotted lines. As space *a* of cylinder *B* communicates through the pipe y_1 with pipe y_2 connecting cylinder *H* to the crankcase, the lubricating oil from space *a* is drained through y_2 into the crankcase, following the path shown by dotted lines in the illustration, and the engine is stopped.

In both cases, when piston *A* is shifted to the left it will produce an equal movement in lever *E*, which through rod *G* operates an electric switch to release the connection between the engine and gearbox when mechanical transmission is used. The stopping device can be reset to the regular service position by means of lever *E*. When the engine is at rest this service position is maintained by a locking peg *R* working in conjunction with the eccentric lever of the governor through a segment. The peg is maintained in the locking position when the engine is idling, or running at the low speed, about 800 r.p.m., provided for use when changing gear, and this prevents the device stopping the engine from idling speed, or when starting a cold engine, when the ratio between pressures *pc* and *pb* is higher than when running normally. If the stopping device itself should fail, its action can be eliminated by disconnecting the locking pin from the governor eccentric lever, thus locking the stopping device in the released position.

Peccavimus

IN describing in the February 17 issue of this Supplement the diesel traction activities on the Norwegian State Railways we stated that the ten railcars recently ordered were to be equipped with Voith hydraulic drive. This was an error. These cars, now under construction at the works of the Strommens Verkstad, actually are being fitted with Lysholm-Smith hydraulic transmission supplied by the A.B. Atlas Diesel, of Stockholm. Each torque converter is being proportioned to transmit 200 b.h.p. at 1,500 r.p.m., and the transmission system incorporates the usual direct drive through a friction clutch over the higher range of speed.

N.S.W. RAILCARS.—During the past four or five months the New South Wales Government Railways have introduced several railcar trains made up of a double-bogie railcar, a second class lightweight trailer, and a first and second class composite trailer. The railcars have a large amount of space for light freight and parcels, to a capacity of about 8 tons, and also seats for 19 second class passengers. Each railcar is powered by two 150-b.h.p. Leyland petrol engines operating in conjunction with Leyland (Lysholm-Smith) hydraulic transmission. These units are allowed a top speed of 65 m.p.h., and are operating on the Narrandera–Tocumwal, Dubbo–Coonamble, and Molong–Dubbo lines.

DUTCH UNDERGROUND DIESELS.—The 28 two-axle diesel locomotives set to work during recent months on the 600 mm. gauge lines in State mines in Holland are powered by Kromhout-Gardner oil engines with six 4¼-in. by 6-in. cylinders developing 65 b.h.p. at 1,300 r.p.m. The four-speed mechanical transmission incorporates a Vulcan-Sinclair fluid coupling, and gives track speeds of 4·2, 5·9, 9·0, and 12 m.p.h. with corresponding tractive efforts of 3,750, 2,200, 1,540, and 1,100 lb. The gross weight is 10·5 metric tons, the wheel diameter 19¾ in., the wheelbase 46 in., and the overall length 17 ft. 8 in. The maximum width is 3 ft. 3½ in., the height 5 ft. 3 in., and curves of 49 ft. radius can be negotiated.

Diesel Railway Traction

Solid Fuel Diesels

THERE has always been some irony in the fact that all the early development work undertaken by Dr. Diesel and his collaborators was financed by money put up by coal interests, for Diesel's original idea was to use coal dust as fuel. Although it was found essential at a very early stage to concentrate on liquid fuel, the idea of pulverised coal has never been entirely given up, and within recent years three separate development programmes have been pursued, *viz.*, by Pawlikowski (at Görlitz), by Schichau (at Elbing) and by Erste Brunner (at Brno). These experiments appear to have reached a stage at which service trials could be made, and it is understood that a 600 b.h.p. slow speed engine embodying both the Schichau and Pawlikowski patents has been ordered in Germany; trials are being made with smaller engines running up to 1,500 r.p.m. Such a stage has been reached only with certain fuels having a negligible ash content, but it is claimed that by the use of special anti-erosive materials the liner and piston ring wear has been reduced to manageable proportions. Two further methods of using coal as fuel for internal-combustion engines are the conversion of anthracite or similar coal to gas in small producer plants carried on the vehicle, and the use of coal gas supplied in compressed form at a gasworks or other supply point. In so far as railcars are concerned the greatest development of the producer gas plant has taken place in countries with little or no coal, where the natural fuel is wood, but the design of coal-burning producer equipment has progressed to at least an equal degree, and there is no reason why producer gas railcars of this type should not be used in England in order to get over the usual objections to oil as an imported fuel.

Gas Turbine Locomotives

A POSSIBLE future variation of the diesel locomotive was discussed briefly by Dr. A. Meyer, of the Brown Boveri Company, in the course of his paper "The Combustion Gas Turbine," read before the Institution of Mechanical Engineers on February 24. This is the gas turbine locomotive, which in the proposals outlined would have electric transmission, although there is no inherent reason why mechanical drive should not be incorporated. In essence, the gas turbine locomotive comprises a combustion chamber in which the combustion of oil fuel under high pressure takes place; the products of combustion are led to a gas turbine which not only drives the compressor producing the forced draught for the combustion chamber, but also drives the locomotive wheels through some form of transmission. An excess of air over combustion requirements is provided by the compressor, so that some cooling effect is given to the walls of the combustion chamber, and the excess air mixes with the products of combustion and cools them to a degree at which they can be used continuously in the turbine without bad effect. A heat-exchanger is included in the circuit whereby the air being furnished for pressure combustion is preheated by the turbine exhaust, and thus the thermal efficiency of the cycle is improved. Dr. Meyer believes that an express 2-Do-2 gas turbo-electric locomotive of 3,000 h.p. could be built on a weight of 135 tons and to give a thermal efficiency at the wheel rims of 17 per cent., compared with the 10 per cent. of a good steam locomotive. As Dr. Meyer indicated in his paper, the problem of getting maximum power from a given bulk and weight may be of greater importance than efficiency, and if a satisfactory machine could be developed it is not improbable that the early applications would be in such a field. Meanwhile, the Swiss Federal Railways have given backing to the proposals by ordering an experimental gas turbine locomotive from Brown Boveri. It is interesting to recall that the peculiarly diesel development, the Büchi-Brown Boveri exhaust gas turbo pressure-charger, assisted in the practical development of the Velox boiler, and thus of the Velox-boilered steam locomotive, but yet further research has brought operations back to something a little nearer "internal combustion," and the boiler has been eliminated. Another type of gas turbine has been built to the designs of Mr. George Jendrassik, and has been tested at the Royal Hungarian Institute for Technology; it showed an overall thermal efficiency of 21 per cent.

Diesel Engine Progress

THE technical development and progress in application of the diesel engine to all forms of power production during the year 1938 is covered in the Bulletin of the Diesel Engine Users Association, which has just been issued. The section on rail traction includes four tables giving the principal characteristics of a short selection of big and small railcar oil engines, engines for shunting locomotives, and two-stroke and four-stroke engines for main line locomotives. Of the railcar engines listed, only three have a specific weight of more than 16·2 lb. per b.h.p., and the lowest value, for an unsupercharged engine, is 10·5 lb. per b.h.p.; the shunting locomotive engines vary from 20 to 59 lb. per b.h.p. and have m.e.p.s at full load of 71 to 92 lb. per sq. in., whereas the railcar engines have values of 82 to 100 lb. in the small high-speed range and 79 to 98 lb. in the bigger medium-speed (1,350-1,500 r.p.m.) models. All the four-stroke high-power engines listed are equipped with exhaust-gas turbo pressure-chargers, and develop m.e.p.s of 115 to 120 lb. per sq. in. at piston speeds of 1,750 to 1,800 ft. per min., and on unit weights of 14·5 to 20·5 lb. per b.h.p. despite a rotational speed of only 700 r.p.m.; this favourable result is one of the benefits accruing from the adoption of pressure-charging. In the comparison of two-stroke engines which is included in the D.E.U.A. Bulletin, emphasis is laid upon the new C.L.M.-Junkers opposed-piston type which, in the 500 b.h.p. size, runs at 1,500 r.p.m. and weighs less than 10 lb. per b.h.p.; but its piston speed is a good deal less than the Harland B. & W. engines, which, although running at only 800 r.p.m., have a fast piston speed owing to the long stroke: bore ratio.

RAILCAR TRACTIVE EFFORT

A study of its characteristics and of the possibilities of increasing the adhesion on driving axles of light vehicles

By Dipl.-Ing. J. L. KOFFMANN

THE general arrangement and location of the power plant of a railcar is determined by the tractive effort required at the wheel rims. The tractive effort itself is a function of the engine torque characteristics, transmission gear ratios and wheel diameter, rail friction, and load on the driving axle or axles. Once the three first components have been determined by reason of power output required, as well as by limitations of space, weight, and existing standards, the only remaining variable is the load on the driving axle.

Both the acceleration and ability to handle trailers, and to run up gradients, depend on the tractive effort available, which, with a double-bogie car having one driving axle is limited by the adhesive weight, as well as by the coefficient of friction between rail and wheel. The friction between rail and wheel decreases as the speed increases, this dependence in accordance with modern investigations being expressed by the formula

$$f = \frac{565}{26 + V} + 11{\cdot}6$$

where f is the friction for dry rails in per cent. of adhesive weight, and V the car speed in m.p.h. The frictional value is reduced to about 70 per cent. with wet rails, the available tractive effort at the wheel rims of the car thus being $T = 0{\cdot}7f \times P$ where P is the load on the driving axle.

Besides depending on the friction between rail and wheel, the actual tractive effort at the wheel rims is also controlled by the general arrangement of motive power equipment, the direction of travel, and by solo operation or trailer haulage. With mechanical transmission the axle drive is fitted with a torque reaction arm, bolted to the casing of the axle drive, the free end being usually located in between rubber blocks, linked to the bogie frame structure.

With a wheel radius r, a torque arm length a, and a vertical force F at the free end of the torque arm, there will be the relation $T \times r = F \times a$ from which $F = \frac{r}{a} \times T$.

With modern railcars $\frac{r}{a}$ is usually about $0{\cdot}4$ to $0{\cdot}6$. With the engine in front of the driving axle, and the car travelling forward, part of the weight, equal to the force F, is transferred from the sprung part of the vehicle directly on the driving axle, and, conversely, the same amount is transferred from the axle upon the springborne part when running in the opposite direction. Furthermore, should a trailing load be dealt with through drawgear at the height h above rail level, a load $L = \frac{T\,(h - h')}{l}$ will be transferred from the front to the rear bogie, and in addition a load equal to $L' = \frac{T \times h'}{l'}$ will be also transferred from the front non-driving to the rear driving axle of the front bogie. In these equations h' is the height above rail of the bogie pivot, l is the bogie centre pitch, and l' is the bogie wheelbase.

In most railcars the difference between h' and h is negligible compared with l, so that the transfer of the load L is of no great importance; but the decrease of the driving axle load by the amount L' when running backwards is important for the acceleration and trailer-handling abilities of the car.

A Typical Example

As a typical example of the problem, the tractive effort curves and tractive effort limits due to adhesion for a 20-ton car with a driving axle-load of 6 tons on the power bogie are plotted in the accompanying graph. Motive power is furnished by a 200-b.h.p. engine running at 1,500 r.p.m. The transmission is of the mechanical type with gear ratios of 4·33, 2·65, 1·68, and 1·09 to 1; the gear ratio of the axle drive is 3·22 to 1, and the wheel diameter is 33 in. The tractive effort curves have been plotted with the assumption of an overall efficiency of 80 per cent. from the engine to the wheel rims, a loss of 20 per cent. being allowed for driving the various auxiliaries and for transmission efficiency. It is evident from these curves that wheel slip will occur not only if the driver should try to utilise the full tractive effort available on the first gear, but also under certain circumstances with the second and third gears in engagement. It would therefore seem advisable to increase the adhesive weight to make better use of the tractive effort available. This can be done at a certain expense by increasing the number of driving axles; or it can be done by moving the bogie centre toward the driving axle, thus increasing the adhesion weight, although at the same time increasing the bogie swing at the front end when passing through curves, and

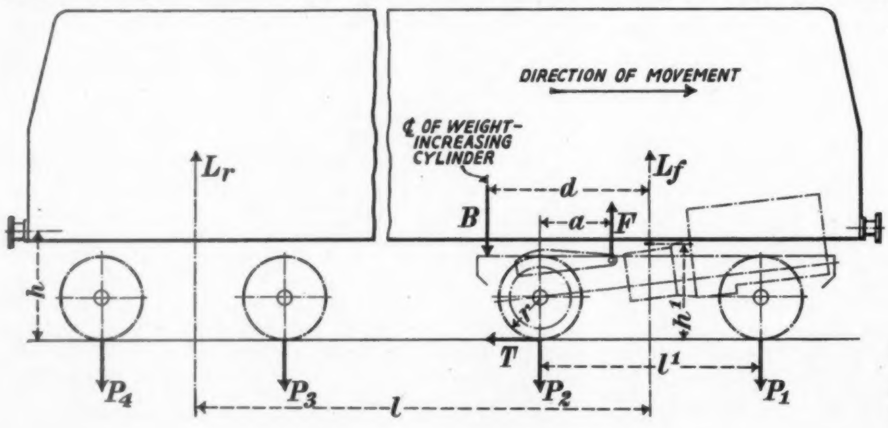


Diagram of railcar layout showing tractive effort and drawbar forces and reactions with a single-engined double-bogie vehicle

thus materially reducing the useful width of the driving compartment with the bogie-mounted engine.

To overcome the difficulties associated with these two methods of increasing the adhesion weight, the writer suggests the use of an auxiliary load transferring device consisting of an air cylinder placed over the rear bogie member, the application of which transfers a part of the load from the bolsters of both bogies on to the driving axles. With a cylinder pressure B applied at a distance d from the bogie centre, the bolster of the bogie concerned will be unloaded by the amount $L_f = B\dfrac{l-d}{l}$ and the bolster of the trailing bogie will be unloaded by $L_r = B\dfrac{d}{l}$.

The various axles of a double-bogie car with the inner axle of only one bogie power driven will be unloaded and loaded (reading from the front) by the amounts

$$L_1 = -B\frac{d - l'/2}{l'} - \frac{L_f}{2}$$

$$L_2 = B\frac{d + l'/2}{l'} - \frac{L_f}{2}$$

$$L_3 = -\frac{L_r}{2}.$$

$$L_4 = -\frac{L_r}{2}$$

Thus loads from the carrying axles are transferred upon the driving axles as long as air pressure is applied.

Taking as a practical example the car mentioned above, the bogie wheelbase is 8 ft., the distances l and d 32 ft. and 6 ft. 6 in. respectively, the load B is effected by a 10-in. air brake cylinder, which, with an air pressure of 70 lb. per sq. in., develops a force of 1·7 tons. The actual load transfer figures are:

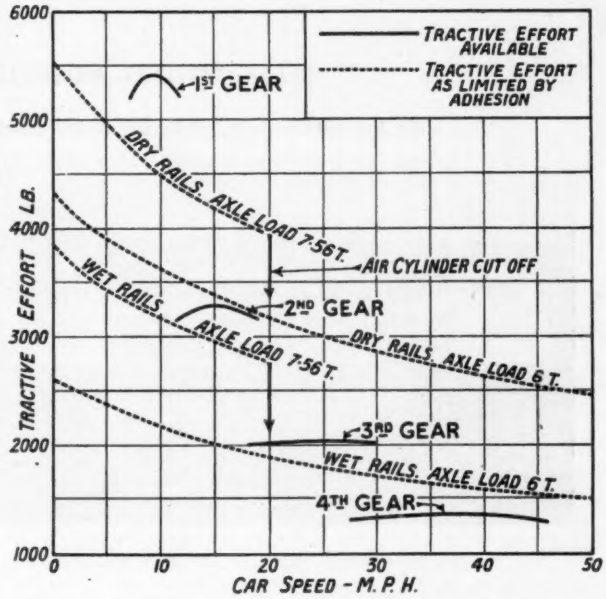
$$L_1 = -1{\cdot}7\frac{6{\cdot}5 - 4}{8} - 1{\cdot}7\frac{32 - 6{\cdot}5}{2 \times 32} = -1{\cdot}21T$$

$$L_2 = 1{\cdot}7\frac{6{\cdot}5 + 4}{8} - 1{\cdot}7\frac{32 - 6{\cdot}5}{2 \times 32} = +1{\cdot}56T$$

$$L_3 = -1{\cdot}7\frac{6{\cdot}5}{2 \times 32} = -0{\cdot}175T$$

$$L_4 = -1{\cdot}7\frac{6{\cdot}5}{2 \times 32} = -0{\cdot}175T$$

The results of increasing the adhesive weight by 1·56 tons is shown by a marked rise of the tractive effort as



Graph showing tractive efforts available under different rail conditions of 200-b.h.p. railcar with four-speed transmission

permitted by the friction between rail and wheel, and a consequent increase of the rate of acceleration and in performance on grades.

The load-transfer cylinder, which can be a standard brake cylinder, is fixed underneath the car floor, and the push rod is arranged to carry a roller, which when pressed upon the rear bogie cross member is not bent sideways by the bogie movement when passing through curves. The application of the cylinder could be left to the discretion of the driver, or performed automatically by an electrically-operated valve energised when engaging the first or second gears, and if necessary, with the third gear also. The first costs of an equipment of this type including a brake cylinder, operating valve, as well as the necessary brackets and piping, should not amount to more than about £40, and the extra maintenance should be limited to occasional inspections.

Black Lights for Driving Cabs

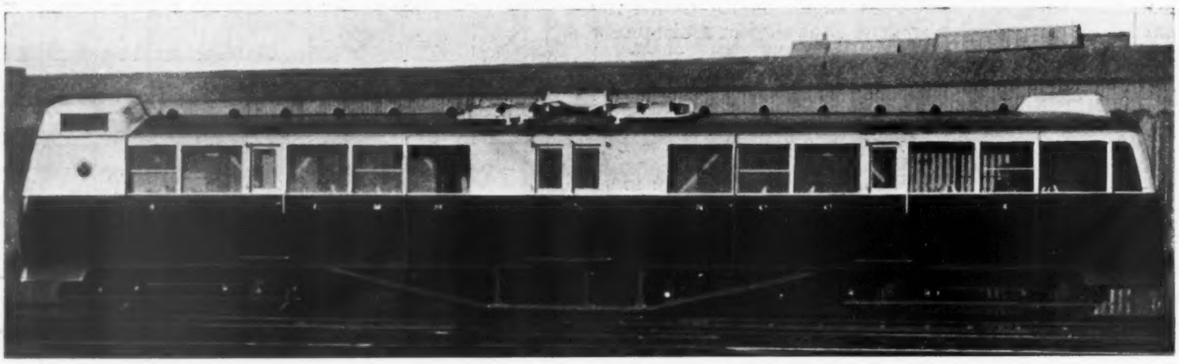
DIFFICULTY is apt to be experienced in observing signals at night when brilliant points or areas of light are used for illuminating the driving cab. A solution now being adopted rests on a principle only recently applied to rail traction, although a rather similar system has been used in aeroplane cockpits for some time. This new method allows only dim lighting of the apparatus dials, control buttons and levers. In essence, the system consists of using zinc-sulphide on these indicators, the phosphorescent elements of which are excited by ultra-violet rays emitted by luminous argon lamps and filtered through a wooden vessel which passes only those radiations which are invisible or very faintly visible. This form of illumination is known, illogically enough, as "black lights." The driving cabin is thus completely in darkness except for the control needles and dials, and the points on the control apparatus, which shine either yellow or green.

These warning lamps are very dull, and those which are of secondary importance are placed outside the driver's range of vision. As all the luminous parts are close together and of little brilliance, the eye remains sensitive to the rays of the signals. Should the excitation by ultra-violet ray be interrupted, the zinc-sulphides have sufficient residual phosphorescence to ensure lighting for some time. Apart from lighting by invisible rays, for use when running, the driving cabs also contain ordinary lighting which may be switched on at stations. Black lights are now being used in the driving cabs of stopping-train railcars, and in the stainless steel electric motor-coaches of the Paris—Le Mans electrified section of the French National Railways.

GAS-TURBINE LOCOMOTIVE.—The Swiss Federal Railways are to try out a gas-turbine locomotive to be built by Brown Boveri on the principles outlined by Dr. A. Meyer in his paper on the combustion gas turbine read before the Institution of Mechanical Engineers on February 24.

IRISH SUBURBAN RAILCAR

25-ton 260-b.h.p. vehicle for trailer haulage on push or pull principle



The latest double-engined 5-ft. 3-in. gauge railcar operating on the northern Belfast suburban services

OPERATING experience with railcars on suburban services to the extent of over 660,000 miles has now been obtained by the Northern Counties Committee of the L.M.S.R., which has just added to its fleet by the introduction of a fourth car, intended to operate on outer suburban and main-line intermediate duties at speeds up to 70 m.p.h. Constructed at the Belfast works of the company to the requirements of Mr. M. Patrick, the Locomotive Engineer, the design of the car follows the general lines of the preceding units, but has a teak-framed body with steel outer panels. Peters' reversible seats are provided for a total of 80 passengers; they are upholstered in blue moquette. Rexine is used for the interior panels. A Clarkson exhaust-gas boiler is installed to cater for the car heating. Light steel pressings are used for the underframe, which is built up on two main outer solebars 14 in. deep 3½ in. wide and 0·28 in. thick; these run the whole length of the car, and are supplemented by strong truss framing and by inner longitudinals between the bogie pivot supports. The bogies themselves are built up of rolled steel sections and have axles carried in Hoffman roller bearings. Vacuum and hand brakes are incorporated. The either-way conning tower drive of the preceding diesel railcars has been perpetuated.

As before, power is provided by two Leyland 10-litre six-cylinder oil engines each set to give a maximum of 130 b.h.p. at 2,000 r.p.m., and supported—along with the transmission units—on subframes below the car floor. The cooling water radiators and tank are mounted on the car roof, and certain of the cooling elements are used to cool the water circulating through the heat exchangers of the transmission torque converters. To each engine is coupled a Leyland (Lysholm-Smith) hydraulic torque converter in which is incorporated a free-wheel. Hardy-Spicer cardan shafts transmit the drive to the reversing and final bevel drives, with a ratio of 3·12:1, on the axles.

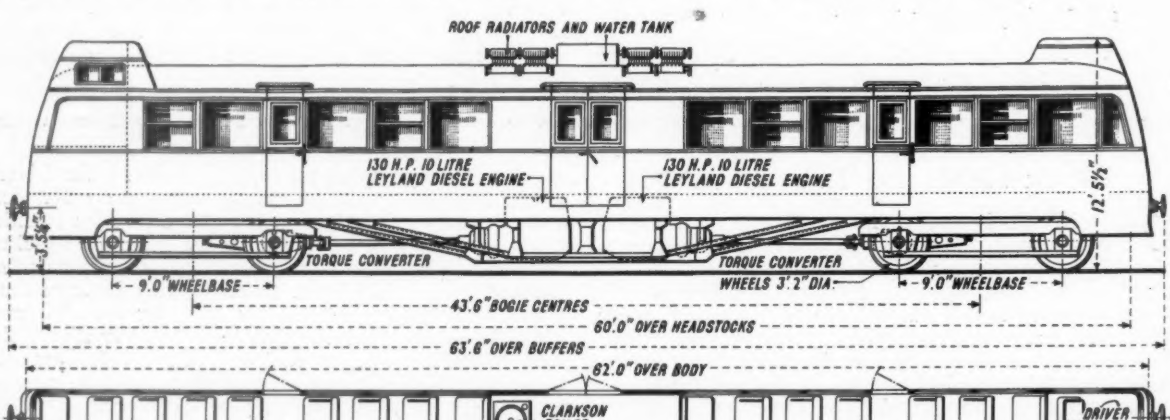


Diagram of No. 4 railcar of the L.M.S.R. (Northern Counties Committee)

THE TRAINING OF RAILCAR DRIVERS

A brief survey of the methods used and the training centres established by the French National Railways and constituent companies

By GEORGES HARCAVI

DRIVERS of railcars on the French National Railways are carefully chosen for their reliability and sobriety; for, like all drivers, they are responsible for the safety of passengers and the keeping of schedules, often at high speeds. The railcar driver must be cool-headed and quick of decision in all circumstances; he must not hesitate to obey signals, and he must be sufficiently familiar with his vehicle to be able to effect a simple repair himself in case of breakdown on the line.

To prepare for these complex duties men who for the most part have had no previous railcar experience, the French National Railways have organised psycho-technical tests and started technical training centres. The first are for the purpose of eliminating over-emotional candidates, and those whose reactions are too slow. There are at present two examination centres of this kind, one being the works laboratory of the S.N.C.F. (Ouest) at Viroflay, and the other the psycho-technical laboratory at La Chapelle (Nord).

Apart from small details, the examinations taken in both centres are based on the same principles, and determine:—

Quickness
Regularity of simple reactions (psycho-motor)
Tests on suppleness of nerve controls
Wandering attention
Logical intelligence and memory

Theoretical and practical instruction is given in special schools in important running depots, where plenty of trained men and the necessary equipment are to be found. The schools at Versailles, Dijon, and Mirecourt give instruction to embryo railcar drivers in general subjects, *i.e.*, petrol and diesel engines, transmission, braking, and the management of different types of railcars over particular sections of line.

After passing the examination set at this stage, the pupil-drivers transfer to the traction depot where the vehicles are stationed, and here they complete their training, specialising in workshop repairs and travelling as spare drivers on various runs. On passing a driving and signalling test, they are fully qualified.

Drivers of railcars on difficult or high-speed schedules are given the grade of principal railcar driver, in the same way as certain steam drivers holding high qualifications over difficult routes. From amongst such drivers and principal drivers are chosen the chief railcar drivers, who are selected in the same way as *chefs mécaniciens* of steam locomotives.

The Dijon School

Rapid development in the use of railcars on the Région du Sud-Est (ex-P.L.M.) system has necessitated drafting an increasing number of drivers and maintenance men to railcar duties, who, for the most part, were quite untrained for such work. Special professional instruction had to be given the staff as quickly as possible, and to meet this need the Dijon-Ville railcar centre was opened on July 1, 1936, as a department of the general traction school. The school is under the control of the chief engineer of the Second Traction Section of the Région du Sud-Est, and is directed by a superintendent.

The courses differ according to the origin of the candidates, and the duties they will be called upon to perform. Drivers are recruited from the personnel of the running department, and from road vehicle drivers and artisans. A first selection is made at the time of the psycho-physiological examination, which is taken by all candidates in the railway works laboratory at Viroflay. This eliminates those whose aptitude does not come up to the required standards for a railcar driver.

Satisfactory candidates are sent to the Dijon centre, where the course of instruction consists of: an eliminatory course lasting a week, to whittle down the pupils; and an ordinary fortnight's course, following immediately on the eliminatory course, and this is given to promising pupils only. Then comes another fortnight's course, available for those who were already authorised railcar drivers before the school was opened, and for those with a fair knowledge of engines.

Theoretical and Practical Instruction

The theoretical course covers vital elementary instruction in simple physics, mechanics, electricity, a simple technological study of internal-combustion engines of the carburettor and compression-ignition types, four-stroke and two-stroke oil engines, transmission systems, lessons on general running procedure, on fire-protection measures, and on special regulations concerning railcar running. Demonstrations and practical exercises carried out in the study room complete the theoretical course. To this end, one part of the room has been specially equipped. Different types of complete engines are grouped there, as well as numerous constituent details, some of which (*e.g.*, injection pump, magneto, and two-stroke diesel engine) are exhibited in section. There are many wall boards and drawings representing different engines. Separate parts and accessories are also on show, as well as explanatory notes on the various types of railcars in service on the system.

Practical instruction takes place between Dijon and Epinac-les-Mines. Four railcars, two petrol and two diesel, now taken out of regular service, are used by the school for this purpose. On passing from this stage, the candidates take a written and oral examination for general classification purposes. The training of student drivers is completed by driving exercises in the railcar centres to which they belong. Maintenance pupils are chosen from workmen who are already well versed in engines. A special course lasting a fortnight completes their theoretical and practical knowledge.

The courses deal chiefly with breakdown repairs, breakages or failures of most frequent occurrence, and the technology of engines and vehicles. They are intended to train the staff to discover accurately and quickly the cause of breakage, and to carry out necessary repairs correctly. Certain of the staff, such as assistant shed superintendents, foremen and charge-hands, took this course together as a special session. The various railcar centres rapidly felt the benefit of these instruction courses, which have given most satisfactory results. The school has made it possible to instruct and organise the personnel required to meet the ever-increasing demand for trained railcar drivers and shed fitters.

DIESEL CARS FOR FREIGHT TRAFFIC

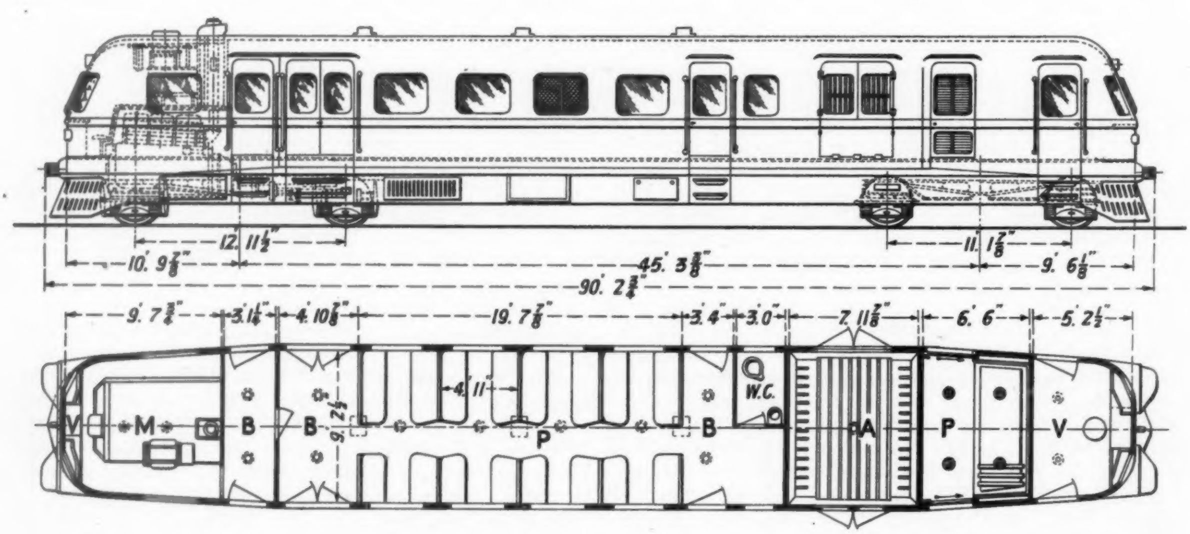
New design caters for mixed freight and mail service, including trailer haulage, on short branch line with heavy traffic in Egypt

THE systematic dieselisation of the Cairo—Helwan line of the Egyptian State Railways has been carried a step farther by the introduction of two railcars intended solely for freight and mail traffic. Diesel traction was introduced on this branch first about the end of 1935, with certain of the 10 Ganz passenger railcars delivered during that year, but in the first half of 1937 a total of 20 further Ganz cars, to operate in close-coupled pairs, was delivered, and took over the working of the entire passenger traffic. The two cars delivered last December, and since put into regular operation, cater for all the normal freight traffic, and are fitted out to carry luggage, light parcels, mails, perishable goods, and livestock, and in an emergency one portion of the car can be equipped with simple passenger accommodation.

There is a driving cab at each end of the car, and at one end this is situated within the engine room. Immediately adjacent to the engine room is an entrance vestibule with hinged doors in the side panel, a hinged door to the engine compartment, and a similar door leading into the largest compartment of the car, namely, that for the carriage of luggage and light goods of all general types. It has a floor area of 252 sq. ft. and is loaded through one double and one single hinged door in each side wall. It is this compartment which is fitted out for the transport of passengers in an emergency, and it has a lavatory located in one corner. Next in sequence is a compartment with a floor area of 75 sq. ft. for the transport of livestock; the side doors comprise a double hinged top portion and a bottom half which swings outwards and downwards, so that it serves as an entrance ramp for the animals. Finally, there is a compartment with a floor area of 59 sq. ft. laid out for perishable goods traffic.

The floors of the engine room, general freight compartment, entrance vestibule and driving compartment are of plywood, 20 mm. thick, and are covered with linoleum. The floor of the livestock compartment is of 20-mm. plywood covered with red fir boards overlaid with oak laths; nine drainholes are arranged down each side near the walls, towards which the floor slopes from the centre line. The floor of the perishable goods compartment is of 30-mm. oak covered with a 20-mm. layer of Induroleum, and water collecting on the floor is drained off through four holes. Red fir side panelling is used for the livestock compartment, and plywood for the remainder of the car sides; all the ceiling panels are of plywood painted white or cream. Insulation of the car interior against external heat is by means of Alfol layers, located between the inner plywood panels and the copper-bearing steel side walls. Body frame and underframe are welded as an integral structure made of 32/38-ton nickel-chrome steel.

Both ends of the car are fitted with standard buffing and drawgear, so that trailers can be hauled when required. Knorr compressed air and hand screw brakes are incorporated. Electric lighting is embodied, and the compartments have 10-watt 26-volt dulled glass ceiling lights supplied from a 360 amp.hr. battery which also furnishes current for engine starting and for other auxiliaries. Apart from the smoke-coloured fixed windows in the driving compartments and entrance vestibules, all the windows in the car can be raised and lowered. The power unit consists of a Ganz VI JaR 170/240 engine set to give a maximum of 235 b.h.p. at 1,300 r.p.m. It drives the wheels through a five-speed Ganz gearbox giving a top track speed of 62 m.p.h. (100 km.p.h.). The bogie-mounted engine projects into the engine room and is covered by a sheet steel casing insulated with cork and Alfol.

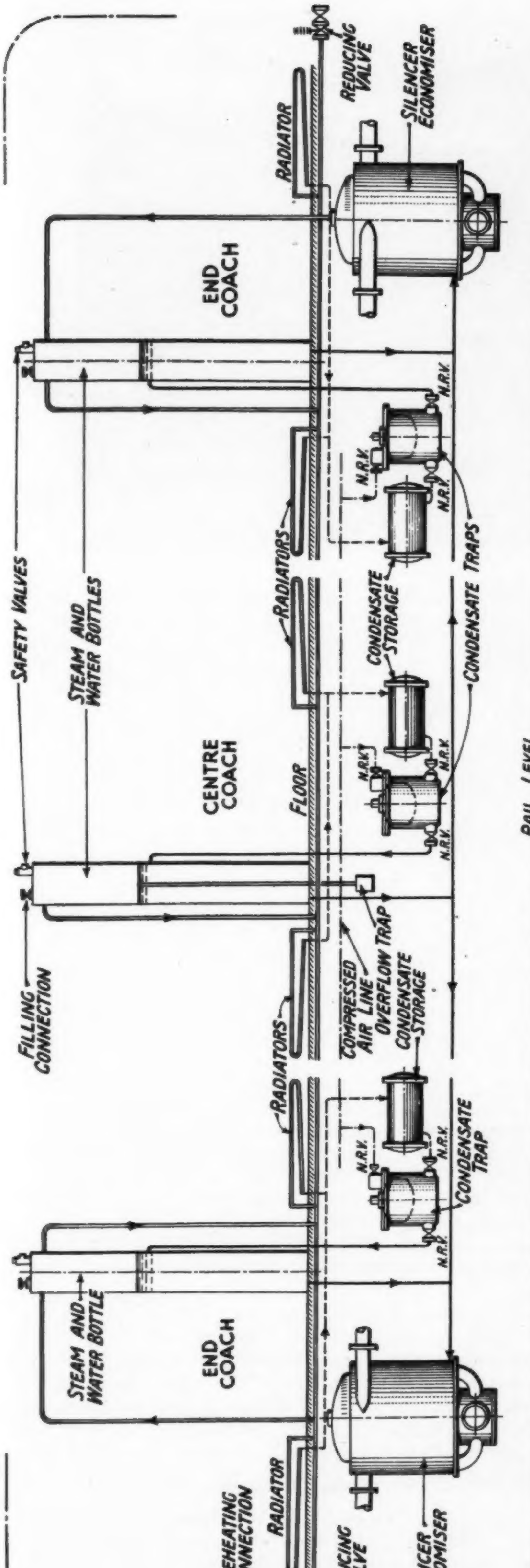


A—Compartment for livestock
B—Entrance platforms

P—Compartment for perishable goods (convertible to passenger compartment)

V—Driving position
VM—Driving compartment and engine room

Layout of Ganz 235-b.h.p. diesel freight car for standard gauge line



Diagrammatic representation of exhaust-gas heating system incorporated in the L.M.S.R. three-car train

RAILCAR HEATING BY EXHAUST-GAS BOILERS

Abstract of a paper read by Mr. H. J. Fountain before the D.E.U.A. on March 8

WASTE heat recovered from diesel engines of single railcars is often used in the form of hot water at atmospheric pressure, which is pump-circulated through standard railcar heaters and returned to the cylinder jackets or to the waste-heat hot-water boiler for recirculation. This system has several good points as regards simplicity and low first cost, but it has definite drawbacks when it is required to pre-heat the railcar before going into service, or when operating in conjunction with other rolling stock. In cases of this kind steam is the most satisfactory heating medium, as the majority of railway coaches are already equipped with steam heating pipes and radiators, and all necessary coupling arrangements. A good many diesel railcars are now in operation using waste-heat steam for heating the coach itself and providing sufficient steam for trailer coaches also.

System for a Three-car Train

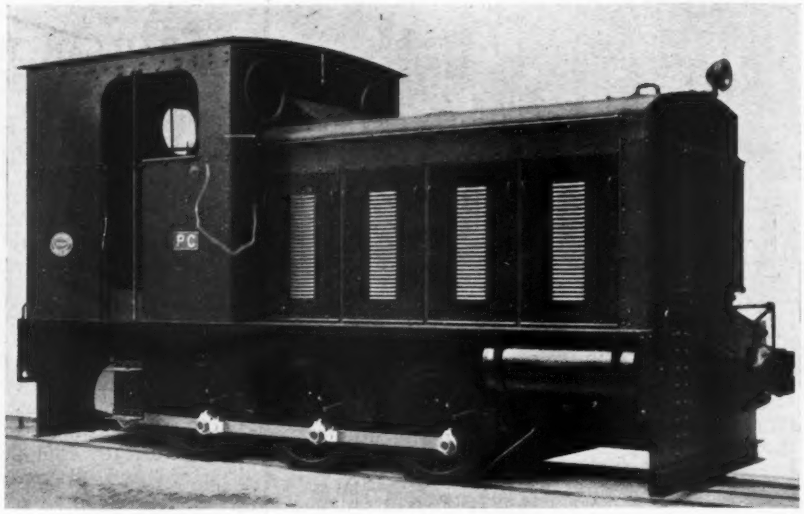
A brief description of the steam heating installation on an articulated three-coach six-engine diesel train, built by the L.M.S.R., will be of particular interest in this connection, as steam at 30 lb. working pressure is provided by the exhaust gas of four of the six diesel engines when the train is operating. The preheating before the day's work is by steam taken from shunting locomotives or from a platform supply. In order to save weight and to prolong the running hours, all the condensate is collected in automatic traps and returned to the waste-heat boilers by means of compressed air. Make-up water is provided from the condensed steam used for preheating. The heat produced by the exhaust gas varies according to the work done by the engines, but the temperature of the air in the coaches compares favourably with that in ordinary main-line rolling stock. The average amount of steam available from the four engines is about 250 lb. at 30 lb. per sq. in. pressure, but this could be considerably increased if desired, as only part of the waste heat is recovered.

Electric-Exhaust Combination

On some Continental diesel-electric railcars, the waste-heat boiler is fitted with electric immersion heaters supplied from the traction circuits during periods of low torque requirements, thus improving the engine's load factor. The engine is started up from cold to drive the main generator, the exhaust gases passing through the silencer waste-heat boiler. The current provided by the generator is connected to the electric immersion heaters in the boiler so that the whole or part of the electrical output from the diesel generating set, plus the heat in the exhaust gases, is used to produce steam for heating the train as quickly as possible. At the same time, the engine is gradually warmed through and is then ready for duty.

When the engine is working at full load, with all current absorbed by the traction motors and with maximum exhaust gas temperature, the steam requirements are always fully met by the waste heat alone. When the train is stopped, or is travelling down long gradients, the current is diverted to the immersion heaters in the boiler to maintain the required steam pressure. This arrangement has considerable advantages for diesel-electric trains, as it is unaffected by the air pressure caused by tunnels, no chimney being involved. It is very simple, and lends itself quite easily to automatic working.

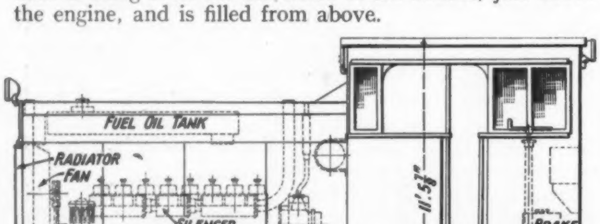
DIESEL LOCOMOTIVE FOR PERU



23-ton locomotive for the Piata-Piura Railway

AMONG the numerous small-power diesel locomotives which are constantly emanating from English manufacturers is a six-wheeled 165 b.h.p. unit built by the Hunslet Engine Co. Ltd. for the Peruvian Corporation. Intended for service on the standard-gauge Piata—Piura Railway, this locomotive weighs 23 tons, and has a maximum permissible speed of 20 m.p.h. The 36-in. wheels are spread over an equally-divided wheelbase of 8 ft. 0 in., and are driven by rods from a jackshaft located beneath the driving cab. The length over buffer beams is 19 ft. 11 in., and the maximum height is 11 ft. 6 in.

An eight-cylinder four-stroke McLaren engine developing a maximum of 165 b.h.p. at 1,000 r.p.m. is installed as the power unit, and is located within a bonnet in front of the cab; it is mounted rigidly on the locomotive frame structure. The normal idling speed is about 300 r.p.m. C.A.V.-Bosch fuel injection equipment is used. Circulating water and oil are cooled in a radiator located at the front end of the bonnet, and made up of Serck elements secured to welded steel headers of Hunslet manufacture. The radiator bank is cooled by a fan driven by vee belts from the front end of the engine crankshaft, and at the same location is a vee-belt drive to the Broom & Wade reciprocating compressor for the brakes. The compressor intake is equipped with a Burgess air cleaner. The fuel tank is slung from the underside of the bonnet, just above the engine, and is filled from above.



Standard-gauge 165-b.h.p. diesel locomotive

Starting of the main engine is effected by a Scott petrol engine operating through a Bendix gear on the flywheel; this small engine is itself started by hand, and the elimination of electric starting removes the main reason for fitting a battery to the locomotive. The electric headlamps and the cab light therefore are supplied with current direct from an engine-driven dynamo, and thus cannot be lit unless the main engine is running, which is not usually a serious disadvantage. The electrical equipment itself is of C.A.V.-Bosch manufacture. Other equipment on the locomotive includes a Westinghouse straight air brake with a self-lapping control valve and an A.T. speedometer and rev counter.

In sequence from the back of the engine the transmission comprises a Hunslet friction clutch, a cardan shaft with Hardy-Spicer flexible coupling, a " clutchstop " or shaft brake, a Hunslet pre-selective four-speed gearbox, and normal type bevel reversing gears mounted above the jackshaft. The gearbox is located beneath the cab floor, and with top engine revs gives speeds of 4, 7½, 12, and 20 m.p.h. As with other installations of the Hunslet mechanical transmission, the control of the gear changing and of the engine throttle is effected through a single handwheel and a clutch pedal, and on the front weatherboard of the cab is a gear indicator showing which step is engaged at any one time. The oil-operating change speed and pre-selective mechanism is erected as a complete unit and secured to the left hand side of the gearbox.

INTERNATIONAL DIESEL SERVICE.—Since March 1 the French part of the both-way evening service between London and Paris has been worked by four-car 820-b.h.p. diesel-electric trains of the Région du Nord. Leaving the Gare du Nord at 16.25, the diesel is due at Boulogne Maritime at 19.05, and leaves again at 20.20, with the passengers who left London at 16.30, arriving back at the Gare du Nord at 23.11.

RAILCARS FOR JAMAICA.—D. Wickham & Co. Ltd. has received a repeat order for two double-bogie double-engined diesel-mechanical railcars for service on the Jamaica Government Railways. The engines are to be of the Perkins light-weight high-speed type, and they will operate through Mylius mechanical transmission.

MAIN-LINE DIESEL CARS IN CENTRAL EUROPE

With tare weight of 38 tons and fully-laden weight of 45 tons, these diesel-mechanical vehicles have 10-12 b.h.p. of engine power per ton of weight

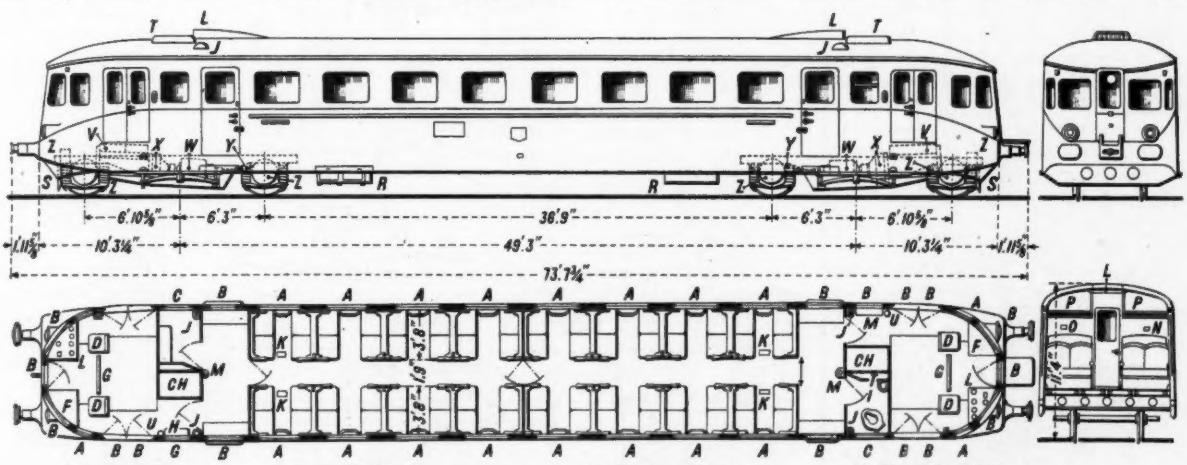
460-b.h.p. trailer-hauling railcar for speeds up to 80 m.p.h.

THE former Czecho-Slovak State Railways were amongst the largest users of railcars on the Continent, and although a great many of the vehicles embody engines using petrol or the national alcohol as fuel, the majority of the cars built within the last few years have been powered by oil engines, the only notable exception being the handful of Slovak Arrow railcars with Tatra petrol engines and Sousedik electro-mechanical transmission.

Most important of the recent main-line developments is the M.260 class of double-bogie car, of 460 b.h.p., designed to haul up to 100 tons of trailers at a top speed of 56 m.p.h., or to operate solo, carrying 64 seated passengers, at speeds up to 75 or 81 m.p.h., depending upon the gear ratio chosen. Multiple-unit control is incorporated. By the use of modern materials and methods of construction, light weight and high specific output have been attained, and every endeavour has been made to obtain smooth riding and easy control. These cars run on standard-gauge tracks and can negotiate curves of 525 ft. radius; they have a maximum axle load of 11¼ tons in the fully-loaded condition.

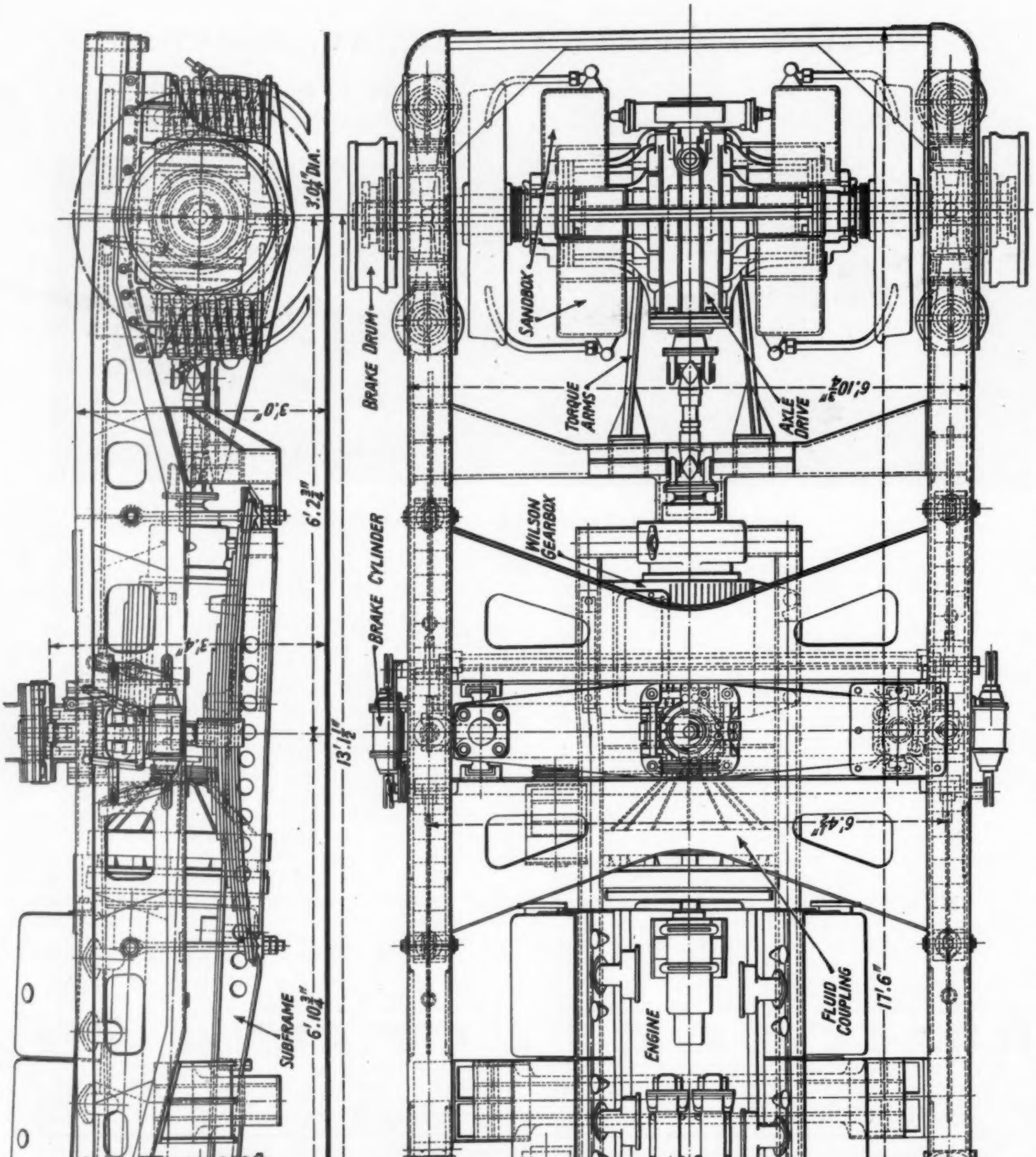
Built by the Ceskomoravska-Kolben-Danek, the car has a body 69 ft. 6 in. long, of welded steel construction, and which follows in contour the standards of previous main-line cars of the State Railways. Body and underframing are of integral construction. Only third class accommodation is provided, and in addition to the 64 seats, arranged two and two on either side of a central gangway, there is room for a dozen standing passengers, a lavatory, a small amount of luggage room, and two driving positions. The roof sheet is of aluminium, and the double wooden flooring, with an air space between the two decks, is covered in linoleum. Heating of the interior is effected by the engine exhaust gases, and there is a double-circuit electric lighting system with 32 lamps in each of the two saloons.

The bogies have a wheelbase of 13 ft. 2 in., unequally spaced, and are pitched at 49 ft. 2 in. centres. The



A—Drop windows
B—Fixed windows
C—Hinged windows
D—Folding seat
E—Control desk
F—Plain desk
G—Protective rail
H—Small oil tank
CH—Fuel and water tanks
J—Exhaust outlet
K—Sandbox covers
L—Car ventilating intake
M—Ventilation shut-off valve
N—Emergency brake
O—Heater control
P—Luggage racks
R—Battery casing
S—Fan covers
T—Engine air intake
U—Fire extinguisher
V—Main engines
W—Wilson gearboxes
X—Fluid couplings
Y—Reversing and axle drive gears
Z—Radiators and brake drums

Diagram of standard-gauge double power unit car built in Prague



General arrangement of standard-gauge power bogie, with 230-b.h.p. engine and gear drive, C.K.D. railcar

36¼-in. wheels have tyres of 47½-ton nickel-chrome steel, and the hollow-bored Poldi C.N.S. steel axles are carried in S.K.F. roller bearings with a journal diameter of 4·53 in. Each box is supported by two triple nests of helical steel springs connected by a short equalising bar below the axlebox, and bearing at the top on a cast steel frame secured to the main side member of the bogie frame structure. The spring wire diameters are 1·02, 0·79 and 0·63 in. respectively, and the corresponding coil diameters 7·9, 5·12 and 3·4 in. To the outside of the main roller bearings are smaller bearings of the same type to support and carry the reaction of the brake drums, which are outside the wheels. Both main and subsidiary bearings are carried in a one-piece cast steel housing which is fitted between guiding surfaces lined with Ferodo. The guides have a patent tapered form to assist in damping out the spring oscillations. Lateral play between bearings and guides is cushioned by rubber blocks.

Two U-shaped pressings and two steel plates are welded together to form the swing bolster, which is supported through links by two long laminated springs, each comprising ten 0·51 in. by 4·75 in. plates, 63 in. long, and located beneath the centre of the main longitudinal members of the bogie frame. The bogie pivot is carried on the top of the bolster and is cushioned by rubber, but it deals with pivoting motion only and carries no weight. The car body load is supported by two sliders on each bolster, and these slides, as well as the end and side thrust blocks of the bolster, are lined with Ferodo, and consequently do not require lubrication. A cross stabilising rod is fitted adjacent to the bolster, to which it is connected through links; it comes into action and is stressed torsionally whenever the bolster tends to tilt longitudinally in relation to the rails. The bogie frame structure itself is made up of two main side members composed of top and bottom channel-shaped pressings connected by welded steel side plates giving the form of a box girder; the end transoms are in the form of a deep box girder of narrow section made up of welded U-pressings and plates, and the centre transoms are deep steel plates welded to the side members.

Engine, gearbox, and fluid coupling are carried on a welded steel subframe having members generally of box section, and supported by a three-point suspension system with rubber cushioning blocks on large rigid cross brackets secured to the bogie side frames. Only one of the two axles—the inner—on each bogie is driven. Pneumatic sanding is fitted to each side of the driving wheels, and in an endeavour to make the bogies completely self-contained, the sandboxes have been located in a most unusual position, being bolted to the casing of the reversing gears on the driving axle; the boxes are filled through trapdoors in the car floor. It was not found possible to carry these boxes on the outside of the bogie frames or on the transoms. Pressed steel torque rods are also secured to the axle drive casing and transmit the reaction to the cross bracket carrying the engine subframe through the intermediary of rubber blocks. At the other end of the bogie is carried a water and oil cooler for the engine and a flexible-shaft fan-drive for the radiator fan. The weight of one bogie complete with engine, transmission, auxiliary and brake equipment, and other details is 22,500 lb.

Braking and Auxiliary Systems

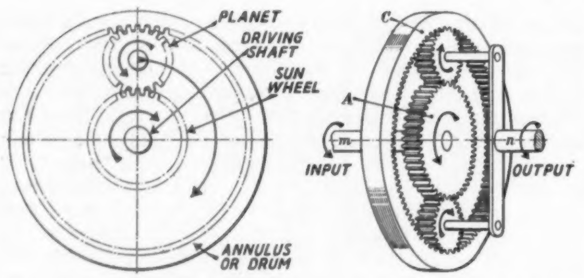
Knorr compressed air brakes are incorporated, and the equipment includes two 4-in. cylinders on each bogie. These cylinders are mounted at the centre of the side frames and their force is transmitted to the drums outside the wheels by links, pull rods, and bell cranks. The mechanism adjacent to the drums is adjustable. The shoes in the drums are of the internal-expanding type, but the provision of special drums is a change from the design of the Slovak Arrow cars, in which the internal-expanding shoes acted on the inside face of the rims of the one-piece wheels. Air for the brake, and for the railcar control, is supplied by a two-cylinder vee compressor on each bogie, driven by a vee belt from the radiator fan shaft and carried on the subframe which supports the radiator. The capacity of each compressor at 1,000 r.p.m. is 850 cu. ft. per hour at a pressure of 85 lb. per sq. in. The air-cooled cylinders are of cast iron and have light-alloy pistons. Air is drawn to the compressor from the roof of the car through a duct containing a filter, and through flexible bellows. The compressor delivery is regulated automatically. A 300-litre main, 70-litre subsidiary, and two 8½-litre auxiliary reservoirs are included in the Knorr brake apparatus. A hand brake is fitted in each driving position and actuates the brakes on the adjacent bogie only.

Engine Equipment

The power plant on each bogie is an eight-cylinder vee four-stroke C.K.D. engine set to give a maximum output of 230 b.h.p. at 1,400 r.p.m. from 150 mm. by 190 mm. cylinders. At this output and speed the m.e.p. is 80 lb. per sq. in. and the piston speed 1,745 ft. per min. The crankcase and cylinder block, and the cylinder heads, are of cast iron. Each head contains one exhaust valve, an inlet valve, and the fuel injector. The combustion chamber is of the Ricardo air-cell pattern; electric starting plugs are fitted. The four-throw crankshaft is carried in five bearings having steel shells with lead-bronze linings and whitemetal inserts; a similar construction is used for the big-end bearings. Each crankpin carries the rods of opposite cylinders. Two camshafts are used, one on each side of the engine, and they are gear-driven from the crankshaft. Bosch fuel injection pumps and nozzles are favoured, and the two four-ram pumps are also gear-driven from the crankshaft, and are located in the neck between the two cylinder banks. Light alloy pistons are used. The pressure-lubrication pump is driven from the timing gears and supplies oil under pressure to the gears, main and big-end bearings, gudgeon pins, camshaft and rocker gear. A suction pump is also included in the lubrication circuit and is driven from the camshaft through a worm gear.

On a forward extension of the crankshaft is a pulley for the belt drive of the cooling water pump, and a flexible shaft connected to this pulley drives the fan of the water and oil radiator; in the hub of this fan is a friction coupling to protect the mechanical parts of the drive from inertia stresses arising from rapid and frequent variations of the speed. The tachometer dynamo is driven directly from the end of the fan shaft. The radiator itself is composed of flat ducts with external ribs, and is carried by an auxiliary frame which also houses the brake air compressor. At the other end, between the fluid coupling and the gearbox, is a pulley for the vee belt drive to the lighting and battery-charging dynamo. The engine is started electrically by a 13-h.p. 24-volt Scintilla starting motor, to which current is fed from a 24-volt 150-amp. hr. alkaline battery, two of which are carried beneath the railcar underframe.

In the cooling water circuit of each engine is a 42-gal. tank located in the adjacent driving compartment, into which the top of the engine projects slightly. The operation of the cooling system is checked thermostatically, and the driving desk contains both pressure and temperature distance indicating lights. The lubricating oil circuit includes a 25-gal. tank from which the oil flows by gravity to the pressure pump, from which it is pumped to the various details, thereafter being drained into the crankcase, where it is picked up by the suction pump, forced



Diagrams I and II, showing respectively a simple epicyclic train and the wheels for second gear drive

through a filter and the cooling elements, and led back to the tank. An Auto-Klean filter forms part of the equipment. A regulating relief valve is fitted to prevent any undesirable increase in pressure as a result of a dirty filter or cold oil when starting. A distant indicator for the oil pressure is included among the driving controls. Above the water tank in each driving compartment is a 77-gal. fuel oil tank, from which the fuel is led through two filters to an 11-gal. auxiliary tank and thence to the engine. The two filters are controlled by a three-way cock, so that either or both of them may be in operation as required, or one of them removed for cleaning while the engine is at work. The fuel tank level indicator can be seen from the driver's seat.

The Transmission System

Behind the engine the mechanical transmission consists of a Vulcan-Sinclair traction-type fluid coupling with a slip of 14 per cent. at 800 r.p.m. and 2½ per cent. at the top speed of 1,400 r.p.m.; a short cardan shaft with flexible couplings; a Wilson epicyclic gearbox with five speeds plus an over-drive speed and a freewheel; and bevel-type axle and reversing gear drives. The fluid coupling enables the load to be taken up smoothly, and makes it impossible to stall the engine by overloading, as an increase in load simply brings down the speed and the driven shaft can actually be stalled under full torque while the engine continues to run at reduced speed.

The Wilson gearboxes in these cars, and in other applications in the same country, have been made by C.K.D., and are known as the Praga-Wilson type; they have been manufactured under licence from the Self-Changing Gear Trading Co. Ltd., in England. The gear ratios in the installations under consideration are first gear 1:8·75, second gear 1:3·71, third gear 1:2·12, fourth gear 1:1·41, and fifth speed 1:1. The ratio of the sixth, or overdrive, speed is 1·36:1. The reversing gears on the axle have a ratio of 1:2·5. These are the figures for a nominal top car speed of about 75 m.p.h. (120 km.p.h.),

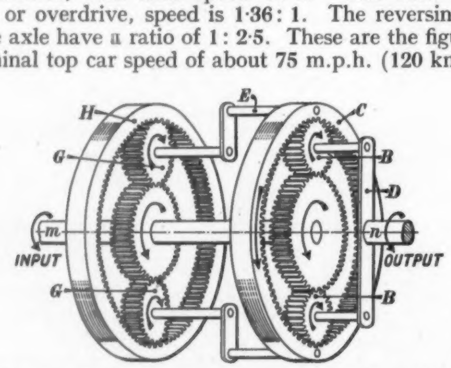


Diagram III, showing sequence of wheels in third gear, Praga-Wilson gearbox

and with an engine speed of 1,400 r.p.m. and new wheels the different gear steps give maximum track speeds of 6½, 15½, 27½, 41, and 58¾ m.p.h., and 79 m.p.h. on the over-drive speed. The respective rail tractive efforts for the railcar are 13,200 (limited by adhesion conditions), 9,500, 5,500, 3,750, 2,750, and, on over-drive, 1,900 lb.

Contained in the gearbox construction are the running gear, the brake bands, the operating mechanism for the brake bands and for the direct drive mechanism on the 1:1 ratio of the fifth gear, the automatic adjusting mechanism for the brake bands, the lubricating pump, and a freewheel of the tapered roller form. The detail construction and operation of the Wilson box have been described in past issues of this Supplement, but it is opportune to recall here the fundamental principles of its design. In diagram I is illustrated a simple epicyclic train; in the centre is the driving shaft, on the splined portion of which is carried the sun wheel; engaging with the sun wheel is the planet wheel which also meshes with teeth cut on the inside of the circumferential drum of the gearbox. Operation of the second gear drive is indicated

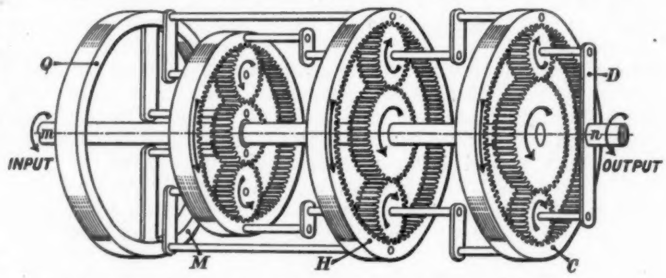


Diagram IV, showing gear trains used to provide fourth gear drive

by diagram II; the driven shaft *n* revolves in the same direction as the driving shaft *m* but with the r.p.m. reduced according to the number of teeth in the sun wheel *A* and the drum *C*. In third gear, as shown in diagram III, use is made of a free drum *C* as well as the fixed drum *H*, thus interposing two sets of planets, *G* and *B* respectively, between the driving and driven shafts. The planets working in the fixed drum *H* are connected to the free drum *C* through the links *E*, and further links *D* connect the planet wheels *B* with the output shaft *n*. Diagram IV represents the scheme of gear trains for the fourth gear drive, where the transmission of the engine torque is effected through one fixed drum *Q*, and three movable drums *M*, *H*, and *C*. Drum *M* is connected through links to the planets operating in drum *H*, and these planets in their turn are connected to drum *C*, from whose planets the final drive is taken to shaft *n* by links *D*. In the boxes fitted to the railcars described in this article, the sixth gear may be considered as an over-speed drive, as its ratio is greater than unity and the driven shaft has a higher speed than the driving shaft. Diagram V shows the gear operation on this step; *a* and *Q* are the fixed drums and *b*, *M*, *H*, and *C* the free drums; the linkage is somewhat more complicated, as the drums are not necessarily connected to the planets on the adjacent drum. Finally, diagram VI indicates the sequence for the first gear drive, which gives the lowest speed of the driven shaft in relation to the speed of the driving shaft. Throughout the whole range the necessary drums are held stationary by external brake bands applied by air cylinders controlled electro-pneumatically from the driving position. The sun wheels, planets, and brake bands are all immersed in oil.

From the final shaft of the gearbox a flexible shaft leads

Diagram V (right), showing gear wheel sequence for the sixth, or over-speed, drive, giving a driven shaft speed higher than that of the driving shaft, Wilson gearbox

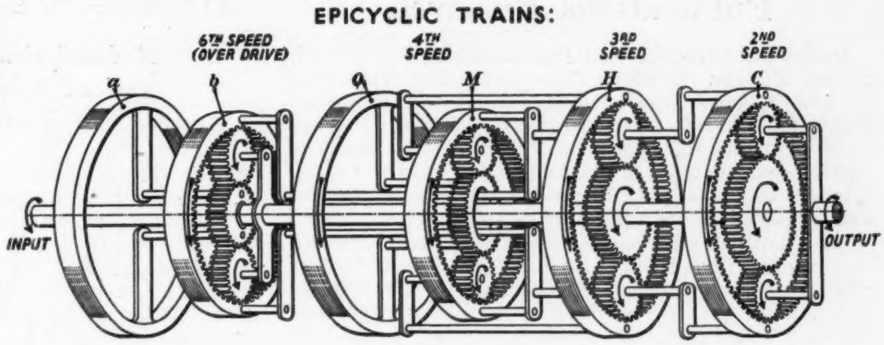
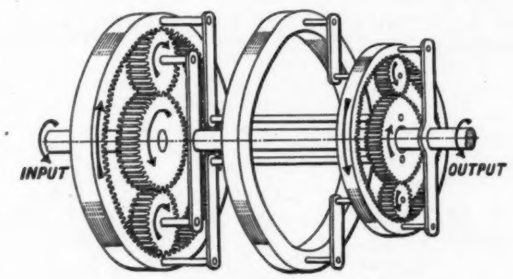


Diagram VI (below), showing wheels used to give first gear drive



to the bevel reverse on the axle. The bevel pinion is in continuous mesh with the two bevel wheels, and a sliding centre coupling mounted on the splined portion of the axle takes up the drive from one or other of these bevel wheels as the particlar direction of motion requires. The pinion, bevel wheels and gear drive casing are all mounted on ball and roller bearings. The sideways movement of the dog coupling is effected by compressed air, the cylinders for which are fed from an adjacent reservoir through electro-pneumatic valves. The cylinder is mounted on the axle drive casing, and its piston is connected to a crank for the movement of the coupling.

Controls

All the controls of both motive power units in the bogies are of the electro-pneumatic type and are centralised in the driving positions at each end of the car. On each driving control desk there are three levers: at the left is the fuel injection control lever, having a back position for stopping the engines: in the centre is the gearbox lever which allows any step to be selected according to the speed of the car and the speed range, 950-1,400 r.p.m., of the engine: and at the right-hand side is a reversing gear control lever, in the movement of which there are incorporated two positions for starting the engines separately. This last lever is mechanically interlocked with the control lever of the Wilson gearbox so that no gear engagement is possible unless the reversing lever is in either forward or backward position. All three control levers can be locked in the neutral position by one movement of a master key, which is the only item carried by the driver when moving from one driving position to that at the other end of the car.

As regards the fuel injection control, each bank of each engine has its own four-ram fuel pump with automatic adjustment of the injection advance to suit the rotational speed. The regulating rods of both pumps of an engine are connected by a common operating mechanism, as indicated diagrammatically in one of the accompanying illustrations. This apparatus governs the fuel injection pump levers over the range from idling to maximum torque in five speed positions, with the addition of a position for closing down the engine. To give this range, combinations of three pneumatic cylinders, N_1, N_2, and S, are used, as follows:

Stop	S
1st engine speed	S and N_1
2nd engine speed	N_2
3rd engine speed	S, N_1 and N_2
4th engine speed	N_1
5th engine speed	N_1 and N_2

The movements of pistons N_1 and N_2 are transmitted through the rod *2* on the lever *3*, from which is subtracted the movement of piston S. Lever *3* transmits the resulting movement through joints on lever *4*, which is securely connected to a shaft carried in two bearings, and on the ends of which are keyed two levers whose function

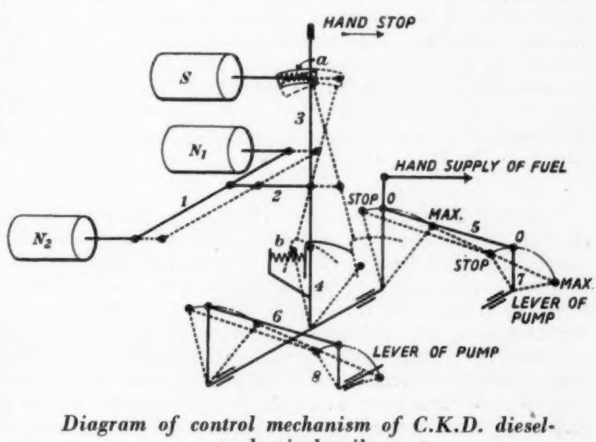


Diagram of control mechanism of C.K.D. diesel-mechanical railcars

is to move the levers *7* and *8* of the fuel pumps by means of the links *5* and *6*. Through the action of the spring *b* of lever *3* the remainder of the pneumatic fuel-governing mechanism remains *in situ*; and this position is used, without air pressure, for the first starting of the engine. For use in the event of a failure of the pneumatic apparatus, there is a manual device located adjacent to the driving position; it comprises a lever and a rope, and when pulled moves the lever *3* and thus brings the levers *7* and *8* into the stop position. The spring *a* eliminates any corresponding movement of the piston in the cylinder S.

New French Railcar Services.—The Région de l'Est has recently extended its railcar services by about 1,000 miles a day with eight Renault AEK railcars delivered since the turn of the year. These cars, each powered by two 150-b.h.p. engines, operate stopping services between Paris, Epernay and Rheims, Paris and Coulommiers, and over the Grand Ceinture between Argenteuil and Juvisy.

Publications Received

Diesel Locomotives and Railcars. By Brian Reed. Second Edition. London: The Locomotive Publishing Co. Ltd., 3, Amen Corner, E.C.4. 8¾ in. by 5½ in. 210 pp. Illustrated. Price 6s. 0d. net.—This book is one of the best of its kind that has appeared. The task of summarising within some 200 pages the history and economics of diesel traction, as well as the extreme variety of engine designs and transmissions systems that have been evolved, presents great difficulties. The application of the internal-combustion engine to rail traction by many independent makers who have brought the engine to a high state of development, but without previous experience of railway work, was bound to result in a great diversity of types, details, and methods, and the necessity of some form of transmission system involves a whole field of machinery in itself, covering many branches of mechanical and electrical engineering. Yet the author never loses sight of the fundamental conditions to which all this prolific development must conform, and his clear descriptions and concise data are held together by a thread of wisdom and common sense which is refreshing in technical literature, and must be of the utmost value to railway staffs trying to sort out the sound and reliable from the speculative and impracticable. Compared with the first edition, sections have been added on brakes and the construction of railcar bogies, bodies, and framing. An illustrated note on the Deutz direct drive locomotive in its present state is included. The engine section has been extended by further material on supercharging and by descriptions of the Gardner, Sulzer, Saurer, M.A.N., and Winton engines. The transmission section has been brought up to date by the inclusion of such systems as the Brown Boveri servo field regulator. But in view of the fact that this form of traction is still in course of rapid development, it is a serious omission that the edition is not dated on the title page.

E. L. D.

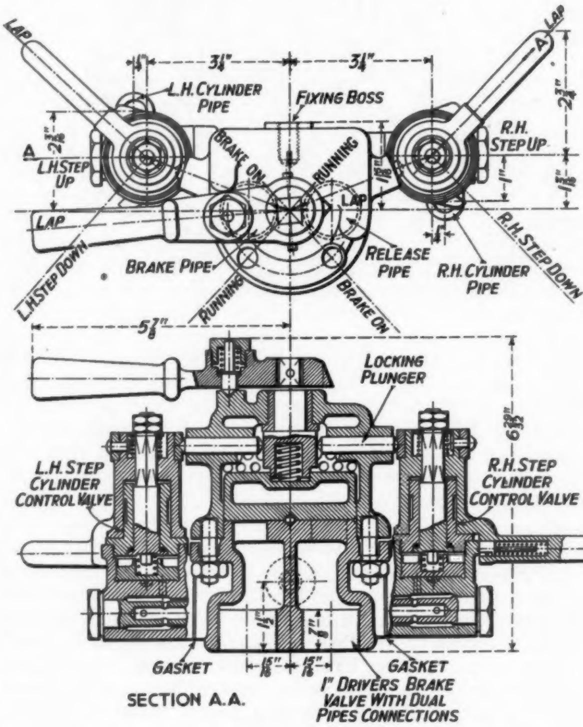
Tables d'Engrenages. By Y. de Molon. Paris: Dunod, 92, Rue Bonaparte (VI). 11 in. by 7½ in. 45 pp. 12 loose charts in pocket. Price not stated. Design of gearing from first principles is somewhat laborious, but if much work of the kind has to be done, some preliminary investigation work to determine the relations between the many variables involved may shorten the process of design by providing data to which reference can be made again and again. The treatise now under consideration is a compilation of such data. By a reference to one or other of the charts provided in a pocket in the back cover the designer can determine immediately those quantities which, though they have to be checked before a design can be passed, are not to be evaluated in the ordinary way without a great deal of labour. Thus, the thickness of teeth at their tips, the greatest stress intensity, the duration of tooth contact, and several other important quantities are often relegated to the position of dependent variable by fixing tentatively the tooth pitch, the pressure angle and one or two other factors; to check such dependent variables from first principles is laborious, but is a simple matter with the help of this book. The early part is a mathematical demonstration of the theory underlying the charts. It is not difficult mathematics, and engineers who are familiar with the subject of gearing. but not so happy with their French, will find that a recognisable formula often provides a clue to the author's meaning.

L.M.S.R. Diesel Service.—On March 20 the L.M.S.R. triple-car diesel train began service on the Midland Division, and makes a daily mileage of 350, running from Bedford to St. Pancras: then a return trip to Nottingham; and finally from St. Pancras to Bedford.

FOLDING STEPS FOR RAILCARS

A description of the equipment used on 3-ft. 6-in. gauge cars in Western Australia

THE six 140 b.h.p. Armstrong-Whitworth diesel-electric railcars running on the Western Australian Government Railways (see issues of this Supplement for April 16, 1937, and September 2, 1938) are fitted with folding steps at the passenger entrance on each side tc make them suitable for operating over country lines where platforms are not available, as well as in more populous districts. When lowered, the steps project well beyond the loading gauge and it was essential to provide means for operating the steps and ensuring that the railcars could not run with the steps lowered. The builders

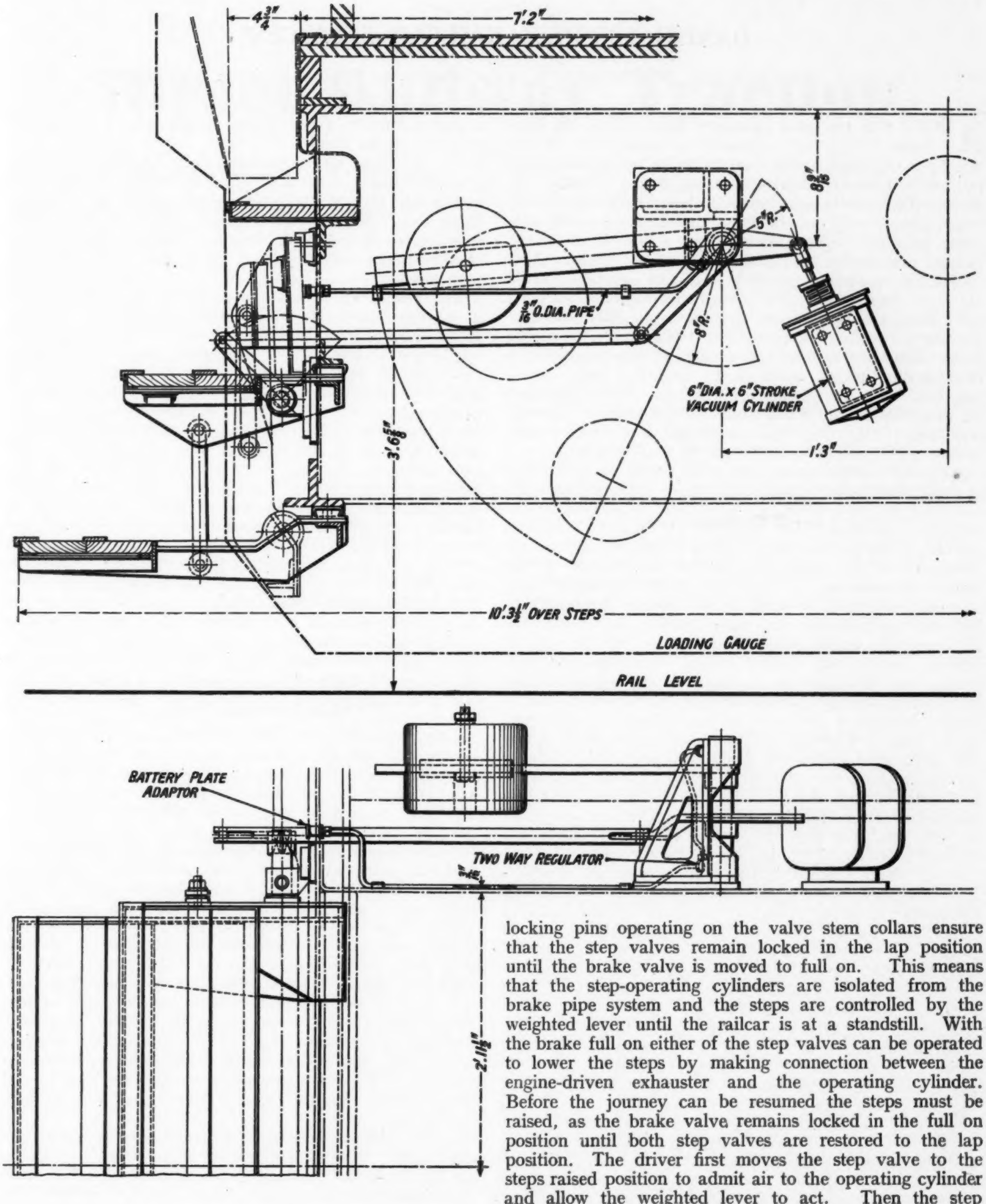


Section through Westinghouse vacuum lap valve showing step locking and control mechanism

incorporated a scheme for the control and operation of these steps which has been developed as a result of collaboration between their Australian consulting engineer, Mr. R. Ross, and the railway engineers. It was decided that the step mechanism should be operated by a vacuum cylinder and interlocked with the vacuum brake.

The neat and simple operating mechanism installed is shown in the accompanying drawings. Normally the steps are held in the folded position by a weighted lever and this gives positive assurance of proper running clearance while the railcar is in motion. A 6-in. diameter Westinghouse vacuum cylinder connected to the brake pipe system supplies power for lowering the steps. Only the driver of the railcar can operate the step mechanism.

Separate control valves are provided for right and left steps and both valves are interlocked with the brake valve, as indicated in the small detail drawing. Simple



Arrangement of folding steps controlled by the vacuum brake system, as fitted to the Armstrong-Whitworth railcars on the West Australian Government Railways; these vehicles were built throughout to the requirements of Mr. J. W. R. Broadfoot, the Chief Mechanical Engineer

locking pins operating on the valve stem collars ensure that the step valves remain locked in the lap position until the brake valve is moved to full on. This means that the step-operating cylinders are isolated from the brake pipe system and the steps are controlled by the weighted lever until the railcar is at a standstill. With the brake full on either of the step valves can be operated to lower the steps by making connection between the engine-driven exhauster and the operating cylinder. Before the journey can be resumed the steps must be raised, as the brake valve remains locked in the full on position until both step valves are restored to the lap position. The driver first moves the step valve to the steps raised position to admit air to the operating cylinder and allow the weighted lever to act. Then the step valve can be moved to the lap position and the brake released.

These steps have proved of real benefit to passengers at stations without platforms and the operating mechanism has given every satisfaction. The pause necessary between the steps up and lap positions of the step valve is very short and does not delay starting of the railcar to any noticeable extent.

DANISH EXPRESS RAILCAR SERVICES*

By C. C. HEDEGAARD CHRISTENSEN, Chief Mechanical Engineer, Danish State Railways

ABOUT half the total passenger train mileage in Denmark is run with internal-combustion or electric power, about a third of it being by diesel-electric railcars and trains. Railcar working began in 1925 with petrol vehicles on local railways, followed by petrol-electric bogie cars, and from 1928 by diesel-electric cars and, later, by diesel-electric locomotives. The diesel-electric railcars are chiefly used with from one to three trailers, to convey passengers to and from the stopping points of the principal trains. Good results having been obtained with the diesel-electric single cars put on in 1932, and now running between Frederikshavn and Flensberg, it was decided to obtain four three-car trains, and these, the Lyntog or Lightning trains, were set to work in 1935, simultaneously with the opening of the Little Belt bridge and the disappearance of the tiresome ferry crossing. In 1937 four four-car Lyntog trains were put into service, and these can be divided into two-car sets if required. All eight trains can be run at speeds up to 120 km.p.h. (74·5 m.p.h.) and higher speeds have been achieved on test.

Lyntog Construction

These Lyntogs have welded steel bodies, and the equipment includes four independent power sets, two per power car, each consisting of a diesel engine, generator and traction motors, the total output being 1,100 b.h.p. Batteries are provided for engine starting, for train lighting when the engine is not running, and for the control system. Any group can be started or stopped independently, but those actually running are controlled together for driving purposes. Each engine drives a d.c. shunt-wound self-cooled generator with a capacity of 320 amp. at 520 volts at 1,000 r.p.m., and supplying current to one 206 h.p. nose-suspended traction motor which has a maximum speed of 1,280 r.p.m. The main generator has a 65-volt starting winding. The electric control is on the Asea-Akerman automatic load regulation system, and there are five controller notches, besides the zero position, for various speeds and loading of the power sets.

Both power railcars of the four-car sets are similarly arranged, with driver's and engine compartments, kitchen equipment, a space which can serve as luggage room or buffet, as desired, and seating accommodation for 40 passengers. The layout includes central gangway, and the seats are of the so-called common class, a combination of the old second and third classes. The seats are in blue leather. The two trailers seat 36 or 42 first-class passengers, in compartments; there is an eight-seat common class compartment at one or both ends in the three-car trains on one such car, and a composite car in the four-car trains. The latter seats 44 or 32 persons and is built like the power cars, but with the seat backs carried up to the roof, practically forming small compartments. The latest trains have air-controlled doors. The heating is by warm water from coke-fired boilers, one to each half train, with electrically-driven circulating pumps. Forced and filtered air circulation is applied to the latest trains, with a pre-heating system for use in winter. Braking is on the Kunze-Knorr system, with the addition of an electro-magnetic rail brake for emergencies. An assistant driver is carried to look after the equipment and help the remainder of the train staff, if required. The driver can summon him by green signal lamps, placed in various positions in the cars.

The principal services consist of six Lyntogs each way daily between Copenhagen and the termini in the north and west, serving not only inland traffic but that to England *via* Esbjerg and Harwich. There is also a north to south service, serving the route between Norway and Germany, but operated by a single railcar hauling ordinary stock.

Each morning three trains leave Copenhagen for the north and west at 10-min. intervals; at noon there is one to the Esbjerg boat; in the afternoon two to the north and north-west 12 min. apart. The three morning trains are conveyed on the same ferry over the Great Belt and similar arrangements apply to the return journeys. Passengers can thus use the ferry as an exchange station. The ferry trips occupy 2 hr. 20 min. on each double journey, which vary from 359 to 663 miles of rail route, some runs including as many as 14 stops and others long distances without a stop. The popularity of the Lyntogs is due to the great saving in time obtained with them. The speeds on up grades are maintained much better than with steam, while the abolition of shunting at the ferry stations enables a train to be put on or off a ferry in 4 min., the least possible time with a steam train being 15 min. Time is also often made up in running, when a delay occurs. It is now possible to go from one end of the country to another and back in the same day conveniently, eliminating sleeping-car charges; some journeys, that formerly took all day or all night, are now possible in a morning.

Mile-a-minute Services

Apart from the ferry time, the Lyntog from Copenhagen to Aarhus, 192 miles of rail route, now requires 3 hr. 12 min., a speed of 60·2 m.p.h.; the previous fastest steam train took 5 hr. 51 min., equivalent to a speed of 33 m.p.h., so that the speed on the rail part of the journey has been improved by 83 per cent.; other routes have benefited similarly. The proportion of the seating accommodation occupied in these trains is efficiently used, being 60 per cent. against 28 per cent. for the entire railway system reckoned over a whole year. The Lyntogs at present make up 8 per cent. of the total passenger train mileage and carry 14 per cent. of the passengers, while they prove to the public that the railways can offer services well able to compete with other systems of transport.

A journey can be made in one of these trains on payment of the ordinary fare, plus the express supplement and seat reservation charge. The first class fare per km. is 7·5 öre, and the ordinary class 5 öre, but beyond 270 km. (167·7 miles) a zone rate applies, diminishing with the increasing distance. Return tickets carry a 25 per cent. reduction.

In the last year the eight Lyntogs have run 1,056,332 train-miles, or 132,973 miles per train, and have effected about 16,156,000 passenger-miles. No mishaps have been experienced and delays due to defects have rarely occurred. Regular inspection and cleaning are carried out at Copenhagen running sheds, and heavy repairs and change of bogies in the shops there. Maintenance costs (wages and material) are 37 öre per train-km., exclusive of management costs; one-sixth of this is due to brake-drum-insert renewals. Fuel consumption comes to 118 litres (about 25 gal.) per 100 train-km. (62 train-miles), costing 8·8 öre per train-km.; lubricating oil costs are 1·5 öre.

* Abstract of paper read before the Central European Railway Association at Dresden, 1938.

Diesel Railway Traction

Diesel Locomotive Weight

WITH the improvement in engine design and the increasing use of exhaust-gas pressure-charging, the unit weights of high-power and medium-power locomotives are now down to scarcely two-thirds of what it was five years ago. For example, the **1,700** b.h.p. main line locomotive of the Buenos Ayres Great Southern Railway introduced in **1934** weighed **195** lb. per b.h.p. in working order, and at that time it was better than the general average, which was about **220** lb. per b.h.p. Within the last two years three European diesel-electric locomotives of over **4,000** b.h.p. have been built with unit weights of **109** to **117** lb. per b.h.p. Although as a general rule the bigger the power the lower the possible specific weight, the new Swiss **1,200** b.h.p. passenger locomotive weighs but **65** metric tons, equivalent to only **120** lb. per b.h.p., so that the advantages of modern design are now beginning to appear in the medium power range. It is true that this locomotive is intended for a top speed of only **68** m.p.h. and therefore does not require the guiding trucks and other mechanical equipment needed for regular speeds of **80** m.p.h. or over. Nevertheless, certain details such as special heating equipment to suit standard electrically-heated carriages had to be fitted, and these provisions have been made in an ingenious manner which added the minimum of weight. On the other hand, American locomotives, partly because of the extensive train auxiliaries such as air-conditioning and high cooking and lighting loads, and partly by reason of the use of numerous rather bulky unsupercharged engines in place of one or two large power plants, still have power-weight ratios in excess of **150** lb. per b.h.p. of the total installed capacity.

More Super-Speed Diesel Services

WITH the inauguration of the summer timetables on May **15**, the Reichsbahn is to extend its high-speed diesel services very appreciably by the introduction of six new return trips daily, this extension being made possible by the **14** triple-car **1,200** b.h.p. Maybach-engined trains which have been introduced into the motive power list since last summer. (See the issue of this Supplement for September **2**, **1938**). The Reichsbahn now has **14** twin-car, **18** triple-car (all Maybach-engined) and **2** four-car (M.A.N.-engined) streamlined diesel trains available for regular operation, and they make a total of **36** independent workings daily. The new services being introduced are Berlin—Frankfort—Basle; Dortmund—Cologne—Basle; Leipzig—Bremen—Wesermünde; Cologne—Leipzig; Breslau—Leipzig; and Dresden—Hamburg. Thus fast cross-country services connecting important industrial centres form the greater part of the new extension, and all of them are at end-to-end speeds in excess of **60** m.p.h. The Berlin—Basle service leaves the German capital at **7.54** and reaches Basle (Badische Bahnhof), **544** miles away, at **16.30**, making a connection there with the Rheingold Express, which is being extended to Milan. Both in this and the reverse direction the train will also serve the Swiss station at Basle. The Cologne—Leipzig *schnelltriebwagen* is to run from Cologne to Hanover coupled to the Fliegende Kölner train leaving Cologne at **7.20**, but in the reverse direction is to run independently throughout. Included in the new Dresden—Hamburg service is a non-stop run of **169·3** miles between Magdeburg and Hamburg, covered in **140** min. The single-journey distances are Berlin to Basle (S.B.B. station) **550** miles; Dortmund to Basle (Bädische Bhf), **420** miles; Leipzig to Wesermünde, **282** miles; Leipzig to Breslau, **240** miles; Cologne to Leipzig, **353** miles; Dresden to Hamburg, **321** miles. An acceleration also is being made in certain of the existing high-speed diesel services, and the westbound evening Fliegende Kölner is to cover the **157·8** miles from Berlin (Zoo) to Hanover in **114** min. non-stop at a start-to-stop average of **83·1** m.p.h.—the fastest railway schedule in the world. From the restart at Hanover the **109·6** miles on to Hamm are booked to be covered at the present timing of **80** min. for the **109·6** miles, equivalent to **82·2** m.p.h. All three Berlin—Hamburg—Altona return services are accelerated to approximately the fastest booking of the Fliegende Hamburger service in the first four years of its operation, *viz.*, to Berlin—Hamburg speeds of **76·3** to **78·0** m.p.h. in each direction. The Berlin—Breslau service also has been quickened by **11** and **13** min. in the up and down directions respectively between Berlin and Beuthen, the start-to-stop speeds over this **204·7**-mile section being now **79·8** m.p.h. and **76·3** m.p.h.

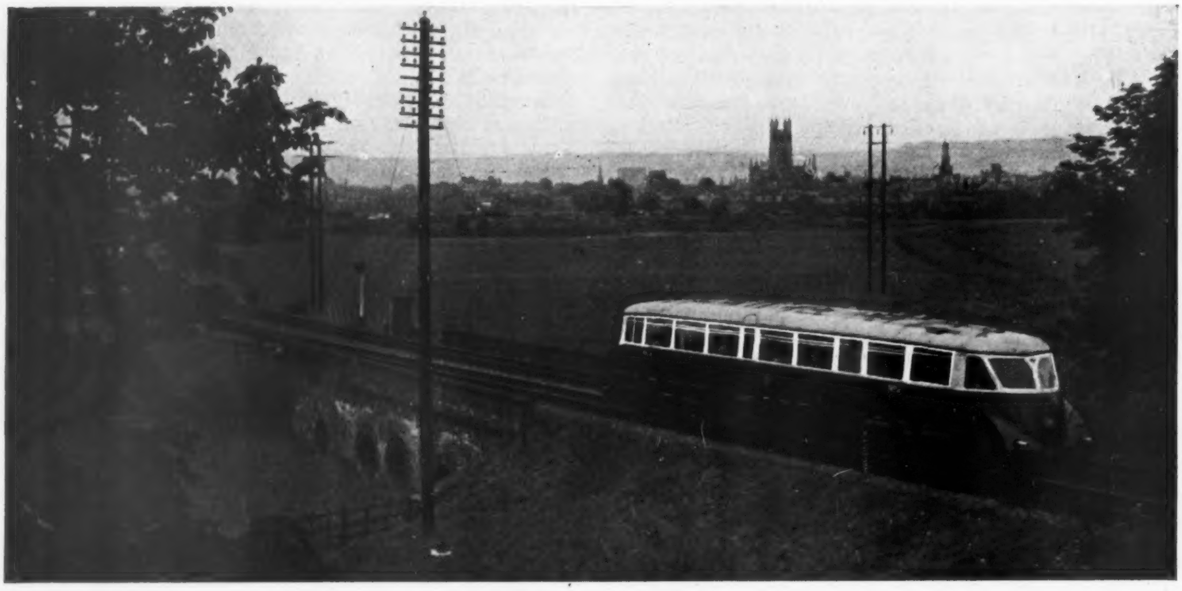
The Use of Sand in Braking

TO obtain the minimum possible stopping distance from high speeds, and to eliminate to some extent the effect of the great variation—anything from **5** per cent. to **40** per cent.—in rail adhesion, it has become not uncommon practice to apply sand to the wheel treads of railcars and high-speed diesel trains when making full or emergency brake applications. Although this has given some satisfaction on railcars and twin-car or triple-car sets, some complication has been made necessary in multi-unit trains, because sand applied to the leading vehicle treads or to those of one or two vehicles is not enough to promote good rail conditions throughout the train, as each wheel clears off some of the sand, and the rails when the rear of the train passes over them are little better than if no sand had been used. On some of the more recent American multi-car high-speed trains, which operate habitually with initial braking ratios of the order of **250** per cent., sanding equipment has been provided at various points down the train, and is operated from the driver's control valve when an emergency application is made. This means increased complication of the control circuits, and the desirability of ensuring that the apparatus cannot be operated when the train is standing or while operating over certain types of track circuit or interlocking mechanism does not introduce any counterbalancing simplification. Moreover, if stops or severe service slacks are frequent on high-speed schedules, the consumption and storage on the train of sufficient sand may become problems, but they are typical of the difficulties encountered when endeavouring to improve passenger train speeds—whatever the motive power—over lines which were not intended for super speeds, and which are enabled to take such trains only by what are, frankly, makeshift methods.

THE DEVELOPMENT OF THE A.E.C. RAILCAR

The progress in design and operation made over a period of more than five years

By C. F. CLEAVER, A.M.Inst.C.E.



One of the A.E.C. buffet cars on the Birmingham—Cardiff service on the outskirts of Gloucester

ALTHOUGH the number of cars working on the G.W.R. is relatively small, they represent the first serious adoption of this form of transport in England, and their services are so scattered that they cover nearly 20 per cent. of the railway company's route mileage; practically every car has to be considered as a separate fleet, and a fleet that has to be kept in 100 per cent. service. The manufacturer has had the advantage of maintaining the 18 cars in service on a mileage basis, and so has been able to see, at first hand, where improvements could be made, and has also been able to take advantage of the advice and suggestions of the railway as to traffic requirements, and thus to produce the best type of car to meet the requirements. The final design is the result of co-operation between operator and manufacturer, as well as of bitter experience of failures and of the steps taken to overcome them.

Types of Cars

Because of the varied duties and location, the cars are comparable with a fleet of buses working over a large area, with the disadvantage of trying to operate economically individual fleets which never exceed three in number. The 18 cars are housed in no fewer than ten sheds, and so form ten separate fleets. They serve 247 stations, and cover a route mileage of 747, extending from Birmingham in the north to Weymouth in the south, and from London in the east to Swansea in the west. In many cases the fleets have to keep 100 per cent. of their cars in daily service. The difficulty of maintaining an economical ratio of men to cars in such small fleets can be appreciated, and as regards variety of service it may be said that average start-to-stop speeds vary from nearly 50 m.p.h. to about 28 m.p.h.; the fleet includes a parcels car and another that is regularly handling trailing loads of 60 tons or more.

The first car was introduced in February, 1934. It is fitted with a single six-cylinder oil engine, and this and the gearbox are of the same design as is used extensively in buses in London. Seating is for 70 passengers and a small luggage compartment is provided; the maximum speed is 60 m.p.h. To date, this car has covered over 250,000 miles at an annual average of about 55,000 miles. The first express railcars began a business service between Birmingham and Cardiff in July of the same year, covering the distance of 117 miles in 2 hr. 25 min. including three stops. These cars are fitted with twin engines, have a speed of over 70 m.p.h. and have buffet and lavatory accommodation; the seating accommodation is for 44 passengers. A year later, three more cars, generally similar to the first, but with twin engines were working in the Oxford and Worcester areas, and ten more cars of the same general design appeared early in 1936—nine for passenger and one for parcels traffic. Three were fitted with lavatories for cross-country traffic between Oxford and Hereford and between Bristol and Weymouth, with a slight reduction in seating capacity. The parcels car is an experiment which has shown excellent results; it is used to pick up parcels and so avoid delay to ordinary passenger trains. This car starts its day's work by taking Messrs. Lyons' supplies from Addison Road to Reading and Oxford, and then returns to London, picking up parcels at all stations; it makes a further return trip to Reading for the same purpose. The average daily load is 1,100 parcels.

An important development in 1937 was car No. 18, which was given a lower gear ratio and standard buffers and draw gear, which enabled it to handle trailers weigh-

ing 60 tons or more. The car runs the eary morning mails from Reading to Basingstoke and then handles all traffic except heavy goods on the Newbury-Lambourn branch. This line was originally a light railway, but needed rebuilding at considerable expense, or it would have had to be closed. This was avoided by using a railcar with reduced axle weights, and the loss in running the line has now been turned into a small profit. The design of the 20 cars now under construction embodies the experience gained from the running of the trailer-haulage car No. 18. As the Birmingham-Cardiff cars have developed more traffic than they can comfortably handle—but not enough to justify a steam train—they are to be replaced by twin-car diesel sets with remote control enabling one man to drive the two cars. Buffets of an improved design are to be provided, as well as lavatories, and the total seating will be increased to 104, the speed remaining as at present.

New Cars

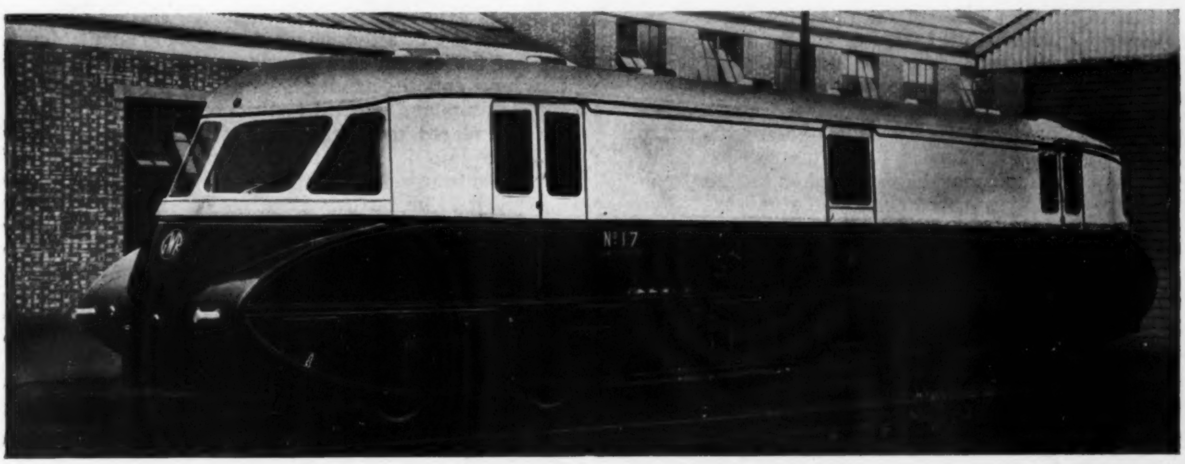
The shape of the new cars has been altered somewhat to give greater passenger capacity. By making the front vertical below the waist-line and by extending the headstock top gusset by 6 in., a total of 3 ft. has been gained without increasing the length over buffers. At the same time, all curves are being replaced by straight lines and flat surfaces. A further parcels car is included in this order. The remaining cars are intended to replace existing push-and-pull trains and will have a maximum speed of only 40 m.p.h. with a corresponding higher tractive effort, enabling them to handle trailers in rush hours. Larger luggage space will be given, and as the seats will be two aside of the gangway, instead of three and two, the capacity will be only 48. One disadvantage of the low gear ratio required for this work is that although it gives the tractive effort necessary for hauling trailers, it limits the speed of the car when operating alone. A new idea is therefore being introduced experimentally on two cars, and comprises dual-range gearboxes, enabling the cars to run at 40 to 60 m.p.h. maximum as required by traffic conditions on ruling gradients.

A great improvement in the riding of these cars has been made by the fitting of shock absorbers. On a train, side sway is controlled by the snubbing effect of the buffers between individual coaches, and some other means of obtaining this effect has to be found for single cars. This has been done by using standard bus-type "Luvax" shock absorbers. Two of these are bolted to a bracket on each solebar of the bogies, and are connected by links to the bolster. Thus side sway is controlled, but not prevented.

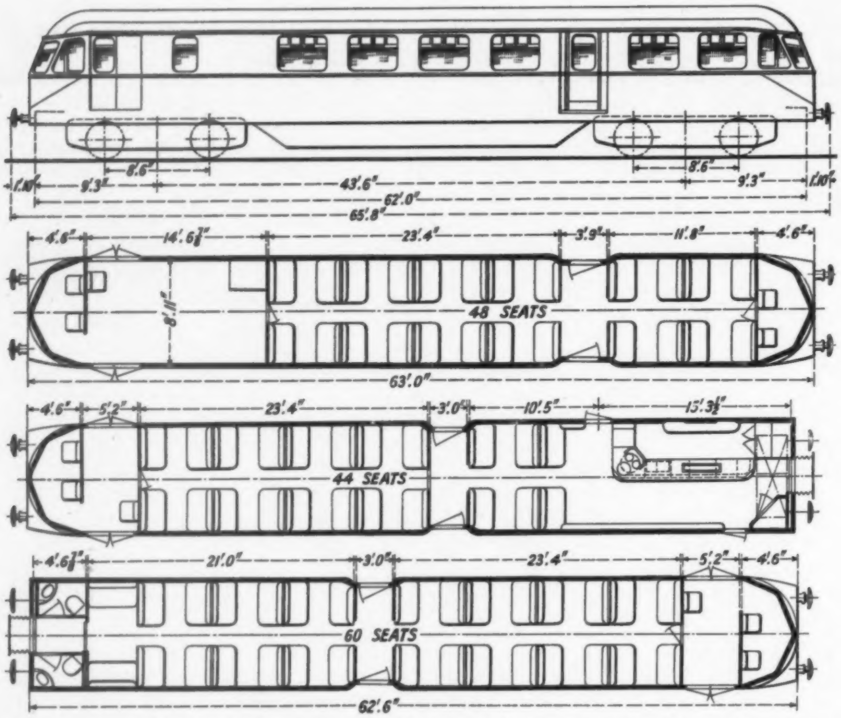
The present fleet of 18 cars is scheduled to run 22,530 miles weekly, or about 3 per cent. of the G.W.R.'s passenger mileage. The number of passengers carried annually by all cars has increased from approximately 641,000 in 1936 to 983,000 in 1938. By the end of 1938 the cars had run over 3,000,000 miles. The average annual mileage of all cars is 53,196, and varies from 68,895 for car No. 10 on the Bristol service, to about 43,000 for the Birmingham—Cardiff cars, where three are kept exclusively on a two-car service; the relatively slow speed No. 18 shows an average of 48,277.

At one end of the operating scale, the Cardiff car makes only 14 stops daily on weekdays and has an average start-to-stop speed of 49·3 m.p.h., while at the other end, the Pontypool car, with no fewer than 167 stops, has a corresponding average speed of 28·9 m.p.h. This comparison does not include the Reading car, which, being intended for trailer haulage, has a maximum speed of only 47½ m.p.h.; making 99 stops daily, its average speed is 23·9 m.p.h. and the distance between stops 2·2 miles. On the Lambourn branch, with a speed restriction of 30 m.p.h., the speed is 21·3 m.p.h. and the distance between stops 1·5 miles.

The most important services are between Birmingham and Cardiff, Oxford and Hereford, and Bristol and Weymouth. Although in many places only one car passes each way daily, there are 12 each way in the Droitwich area. The service between Bristol and Cardiff is possibly unique, as the car—passing through the Severn and other tunnels four times each way daily—runs 13 per cent. of its mileage underground. This service brought to a head an interesting problem. Complaints had been received from gangers that when working near bridges or level crossings it was difficult to distinguish between the horns on railcars and those on road vehicles, and in the Severn tunnel it was impossible to hear them at all. A number of tests were carried out with all sorts of warning devices before the present equipment was adopted, consisting of no fewer than eight Desilux horns per car, four at each end. The two main horns at each end are operated from a supply of compressed air; they are tuned an octave apart and sounded alternately, to make them absolutely distinct from road vehicles, and they can be heard about 3½ miles away. To provide for times when the air pressure has not been built up, two similar horns, but of less



The 260 b.h.p. car used for parcels service on the Thames Valley lines of the Great Western Railway



Diagrams of the 20 new double-engined 210 b.h.p. diesel-mechanical railcars being built to A.E.C. designs for service on the Great Western Railway. The illustration shows the different layouts of the interior which are to be used, and the difference in the end contours compared with previous A.E.C. railcars will be noted

power, are provided, and these are operated by individual electrically-driven compressors.

These 18 railcars have never been intended to put up spectacular runs, but rather to provide useful cross-country services at moderate speeds. All cars except Nos. 1 and 18 are governed at about 73 m.p.h. At the moment of writing they make 13 runs daily at start-to-stop speeds of 50 m.p.h. or over, covering a total of 465 miles at an average of 53·3 m.p.h. Included in these runs is one by car No. 1 which, although fitted with only one engine, makes a 19¼-mile run at 48·1 m.p.h. start-to-stop. The cars are often hired by private parties, and high speed running has been recorded. On one occasion, the distance of 77¼ miles from Swindon to Paddington was covered in 70 min. at an average start-to-stop speed of 66 m.p.h. On a test run, No. 18 (with suitable gear ratio) ran from Oxford to Paddington, 63½ miles, in 65 min. including two intermediate stops, covering over 40 miles at 68½ m.p.h.; the same car with different ratio and hauling two trailers, making a total weight of train of about 90 tons, ran from Southall to Newbury, 44 miles, in 63 min.

The same general arrangement of chassis is used on all A.E.C. railcars. The engine and transmission units are carried on the outside of the underframe and below floor level, with the final drive in the axlebox itself. In this way, any unit may be easily taken out and replaced, and no floor space is sacrificed. In railcar No. 1 the engine is mounted on the side of the underframe, slightly ahead of the centre of the car, and the drive is taken through a fluid flywheel and cardan shaft to a four-speed Wilson gearbox. From here, again by cardan shaft, the drive passes to a reverse box, and thence to the worm drive in the axlebox on the outside of the wheel of the inner axle of the bogie. A further shaft connects this box to the outer one, giving a two-axle drive.

In cars 2 and 7, the same arrangement is followed, but is duplicated, the engine on the right-hand side of the chassis driving the leading bogie, and the left-hand one the trailing bogie. The only difference is that one gearbox was omitted, giving direct drive on one side and indirect on the other. Difficulties were experienced on these cars in controlling the engine speed on the direct side when the other was in an indirect gear, but this was overcome by a cam arrangement connected with the pre-selecting mechanism. No. 7 car was fitted experimentally with a gearbox on both sides, and the improvement in acceleration was so marked that the next ten cars—Nos. 8 to 17—were all fitted with two boxes. The single gear-box cars only drive on one axle on the direct side, a single axle providing all the adhesion weight necessary for the reduced maximum tractive effort. In No. 18 car, the reverse and final drives were combined in the axlebox, and due to the reduced length of transmission the two engines were carried on a subframe opposite one another at the centre of the car. This concentration of weight has resulted in a certain amount of side-sway, and the original staggered position of engines has been re-adopted for future cars.

The radiators are placed behind the engines and cooled by two fans directly mounted on countershafts forming part of the cardan drive from engine to gearbox. These fans have opposite-handed helices and draw the air through the radiators and expel it endwise. The radiator in No. 1 car was placed across the front of the engine and air was deflected into it by a swinging flap from between the frames outwards. The position of the seats in the body allowed it to be carried above the top of the underframe. In later cars it was not considered advisable to draw air for both radiators from inside the frame, and seat positions restricted the height. Air is drawn from the outside of the car, and to compensate for loss of height the radiators are made wider and carried at 45° to the frame to keep inside the loading gauge. Louvres and a swinging flap divert the air into the radiator in whichever direction the car is travelling. In car No. 18 the radiator is ahead of the engine but is placed in line with it, instead of at right-angles, and the fan, which is belt-and-bevel driven, has its axis at right-angles to the centre line of the engine. Radiators on future cars are to occupy a similar position, but will be behind the engine, and two

fans will be used with their axes in line with the engine crankshaft and having opposite directions of pull.

All cars now running have six-cylinder A.E.C.-Ricardo engines with a bore of 115 mm. and stroke of 142 mm., and at a governed speed of 2,000 r.p.m. develop 120 b.h.p. As they have to develop maximum power continuously for long periods they are fitted with oil coolers in the sump, consisting of gilled tubes forming a grill over which all return oil is sprayed. Water from an auxiliary radiator is passed through the cooler, and this radiator is made up virtually of one continuous tube about 30 ft. long, instead of a series of tubes in parallel, resulting in a relatively large temperature drop in a small quantity of water, instead of a small drop in a large amount of water.

In future engines the direct injection principle will be used in conjunction with a cylinder bore of 120 mm. and the governed speed will be 1,650 r.p.m. The resulting b.h.p. of 105 is considered sufficient for the reduced speed required of these cars, and will be compensated for by an increased tractive effort at lower speeds; in addition, the maintenance should be reduced. An oil cooler of an improved type has been designed, and this can be withdrawn for cleaning without dropping the base.

Four of the 18 cars are regarded as spare; this may seem an excessive proportion, but the cars are shedded at ten depots. One car is retained solely for the Birmingham—Cardiff service, and another is always at the manufacturer's works for periodical overhaul; to maintain continuity, a second car is sent to the works for overhaul when the previous one is ready for test, and allowance has to be made for body maintenance and painting at Swindon. Nominally, one spare is held at Birmingham for the service there to Cardiff, another at Worcester, and one on each side of the Severn tunnel at Bristol and Newport.

Overhauls

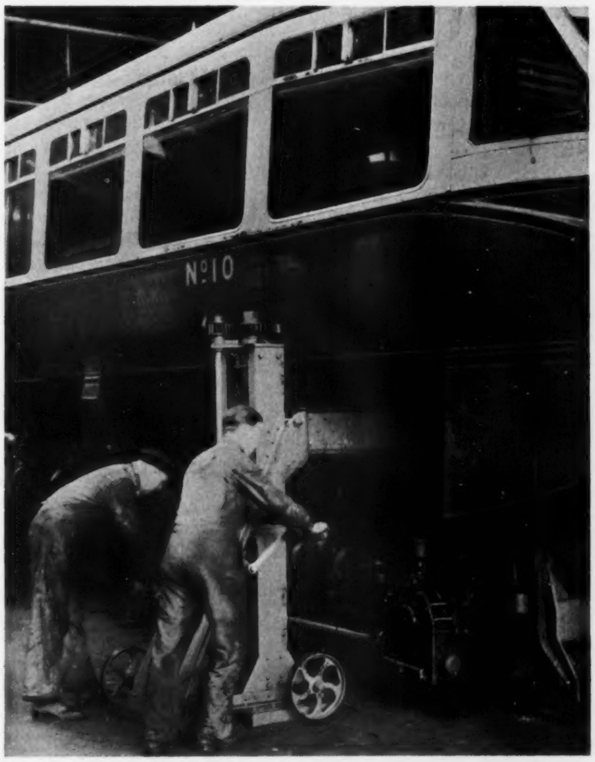
It has been found most convenient to carry out periodical overhauls at the makers' works at Southall, where a permanent staff is held for this purpose, and whereas medium overhauls were originally made at 25,000 miles and heavy at 50,000, it has been found possible to extend these periods to 35,000 and 70,000 miles respectively. Service representatives of the manufacturers are stationed at Birmingham, Oxford, Newport and Bristol, and they are responsible for the examination of cars in their district, as well as for running and emergency repairs and adjustments. They also make periodical runs on the cars themselves, to check up running and to give advice to drivers where required. Maintenance work as a rule has to be undertaken at night.

Weekly reports on each car are sent in to the manufacturer's headquarters, and these reports are entered on tabulated sheets, from which the condition of cars can be fairly accurately gauged, and the sequence of routine examinations ensured. The railway company is responsible for lubrication, fuel, &c., and has its own tickler cards, which cover daily, weekly and four-weekly servicings; and the manufacturer's representative is always present at the four-weekly inspection when all oil is changed and other major examinations carried out. For the periodical factory overhauls at Southall, a shop is used having four roads, each more than long enough for a car, and one has a pit in excess of the length of a car. The capacity of the shop is thus enough for servicing, as well as for turning out about one new car a week.

At the intermediate (35,000-mile) overhaul the following work is carried out. Engines are examined, pistons taken out and new rings fitted; bearings are taken up and valves ground in. Water pumps and their drive are overhauled; flywheel glands and races are examined, and the crankshaft oilways are cleaned out. Timing gears are inspected; injectors reset, and the sump and oil cooler thoroughly cleaned. Gearboxes and reverse boxes are thoroughly cleaned and receive careful attention, and the former are checked for selection and adjustment. Axlebox parts and propeller shafts are examined for wear; brake cylinders are taken down and cleaned and all brake gear thoroughly inspected. All other parts of the chassis are looked over to make sure that they are in perfect working condition.

The procedure at a heavy overhaul is the same except that engines, gearboxes and reverse boxes are taken out, stripped down, and completely re-erected. Radiators are taken down and thoroughly cleaned out and painted internally. Axleboxes are stripped, and as at this mileage the tyres usually need turning or replacing, the bogies are withdrawn. To do this the car is lifted by means of four screw-jacks, manually operated, and working in pairs carrying a cross bar passing below the car underframe. This method may not seem very economical but in view of the number of lifts that have to be made, a pair of 25/30-ton overhead cranes, with the consequent increased height of the shop, would not be justified. Actually the time required to lift a car, including preliminary jacking up to put in the cross girders, is from 12 to 13 man-hours, and taking into account the mileage at which lifting is necessary, this lifting and subsequent lowering works out at about 0.015d. per mile.

While the tyres are receiving attention the bogies are thoroughly examined as regards their bolster rubbing plates, horn cheeks, swing links and all other details. At the same time, the underframe is checked for rivets, bogie pivots and any parts which may show wear. A competent electrician is permanently employed to ensure that all starters, motors and wiring are well kept.



Lifting of a railcar for heavy repairs at the Southall works of the A.E.C.

DIESEL TRAIN OPERATION IN HOLLAND

Some notes on the design of the new five-car diesel-electric trains, and on the performance of the 20 three-car sets built in 1934 and used on various main-line passenger services

A twelve-car diesel-electric train made up of four three-car formations

THE eighteen five-car diesel-electric trains ordered some little time ago by the Netherlands Railways are intended to supplement the work now performed by the 20 trains put into traffic in 1934, so that on all the non-electrified lines the principal fast and semi-fast passenger trains, with the exception of international services, will be diesel-operated. Of the new order, 18 trains are to be powered by Maybach-type engines, three Büchi pressure-charged 650 b.h.p. diesel-generator sets to each train, and the two emergency power units are to be provided with Stork-Ganz engines. Actually a total of 63 Maybach engines has been ordered, 54 for the first installation and nine as spare units.

New Design

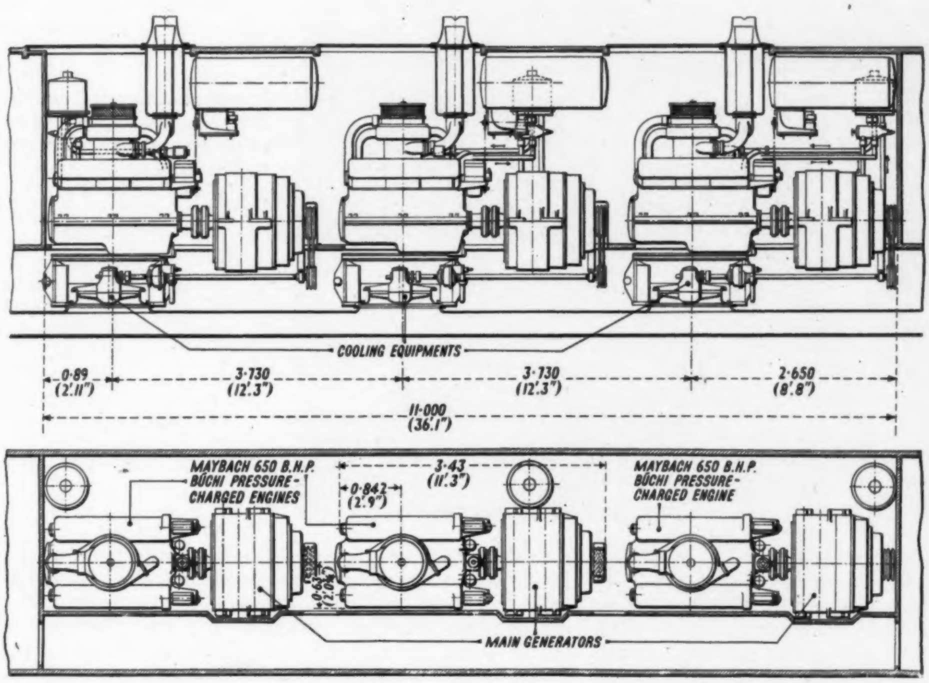
As with the trains built in 1934, the new sets will have a special power car, carrying on the underframe the engines, generators and main control and auxiliary equipment. These power cars will be built, and the engines assembled, at the Werkspoor factory, and the passenger vehicles constructed by other Dutch carriage builders. The power sets are to be located in line, one behind the other, and each will have its own Maybach cooling equipment located beneath the floor and with the fan shafts driven from the engine crankshafts. The engines themselves are to be of the well-known vee type with twelve 160 mm. by 200 mm. cylinders pressure-charged by a Büchi exhaust gas turbo blower mounted in the angle between the two cylinder banks. The engine speed is 1,400 r.p.m.

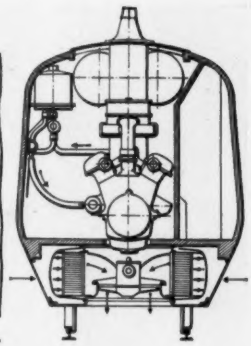
In each train the first car will have second class accommodation; the second car will house the power equipment and a luggage room; and the next three cars will have third class accommodation, all on similar lines to the interior of the 1934 diesel trains. At each end there is to be a driving compartment. Multiple-unit control is being incorporated, and the intention is to operate the sets regularly in formations of two or three, as is done with the present three-car sets, which often are made up into trains of nine or a dozen cars.

Services Operated

The 20 trains set to work in 1934 resulted from a decision made in 1932 to try diesel instead of steam at a time when new motive power had become necessary. The introduction of electric traction on the central main lines (Amsterdam—Utrecht—Eindhoven and Rotterdam—Utrecht—Arnheim) was then considered to be uneconomical, more particularly owing to the high cost of current, about 0·032 fl. per kWh. From 1935 onwards these 820 b.h.p. diesel trains proved effective in reducing the drop in passenger traffic, and even in increasing it, to a point at which, in conjunction with the lower cost of current which had become possible, 0·015 fl. per kWh, and the lower consumption of the modern electric trains derived directly from the design of the diesel sets, conversion became feasible, and electric traction was introduced on the central lines in the summer of 1938. The diesels were then moved to other routes, and about the same time or a little earlier powerful single-unit diesel cars were introduced on certain secondary routes as indicated in the issue of the *Diesel Railway Traction Supplement* for November 27, 1936 and January 21, 1938.

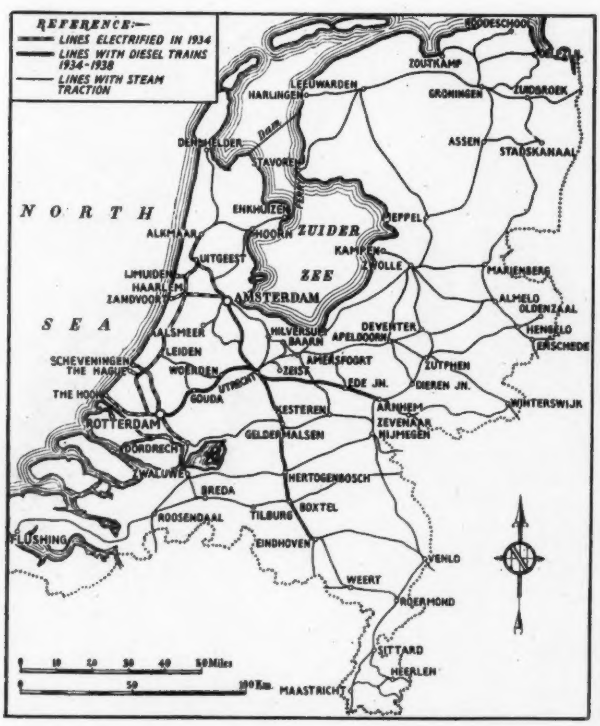
When operating on the central lines, and since the summer of 1938 on the Groningen, Hengelo and Maastricht routes, the diesel trains have been worked on a systematic timetable giving fast short start-to-stop runs, providing good connections at various junctions in addition



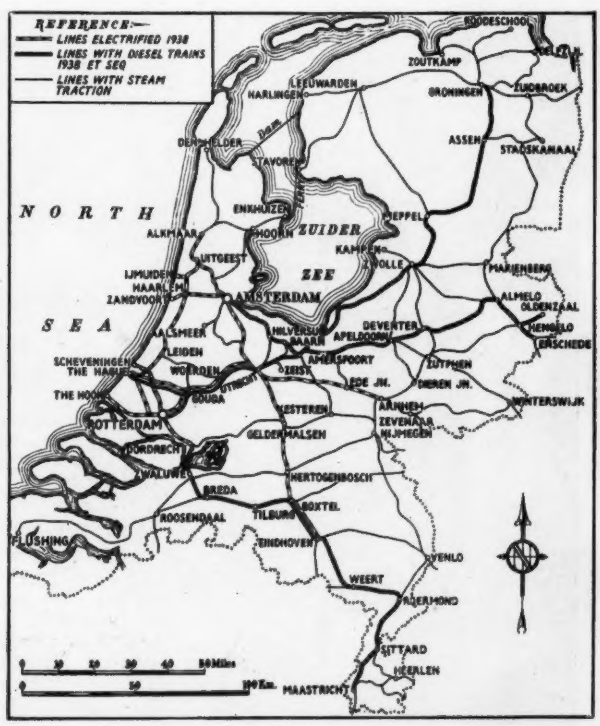


General arrangement of the three Maybach 650-b.h.p. vee engines with Büchi pressure-chargers in the new Dutch five-car diesel-electric trains

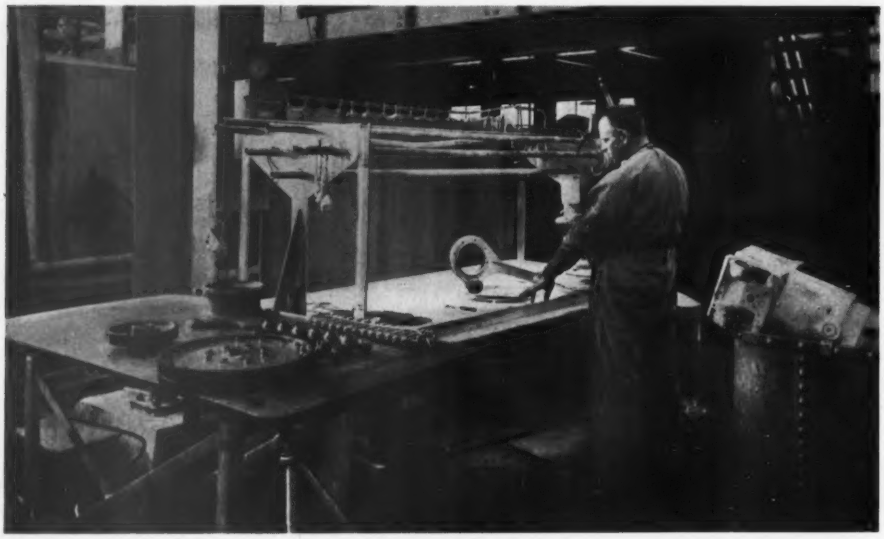
to rapid end-to-end travel. The diesel trains now are allowed a top speed of 75 m.p.h., whereas the steam trains cannot be allowed a limit above 62 m.p.h. for regular work. This system of operation was extended to cover all main lines—electrified and diesel-worked—with the inauguration of the summer timetables in 1938, and practically all the principal Dutch lines now have a regular two-hour express service, and certain lines have a frequency of one or one-and-a-half hours throughout the day. This big increase in the number of fast trains stopping at junctions and medium-sized towns was carried out coincident with the closing of a total of 148 very



Map showing diesel and electric services on the Netherlands Railways during the years 1934 to 1938



Map showing location of lines with diesel and electric services from the summer of 1938 onwards



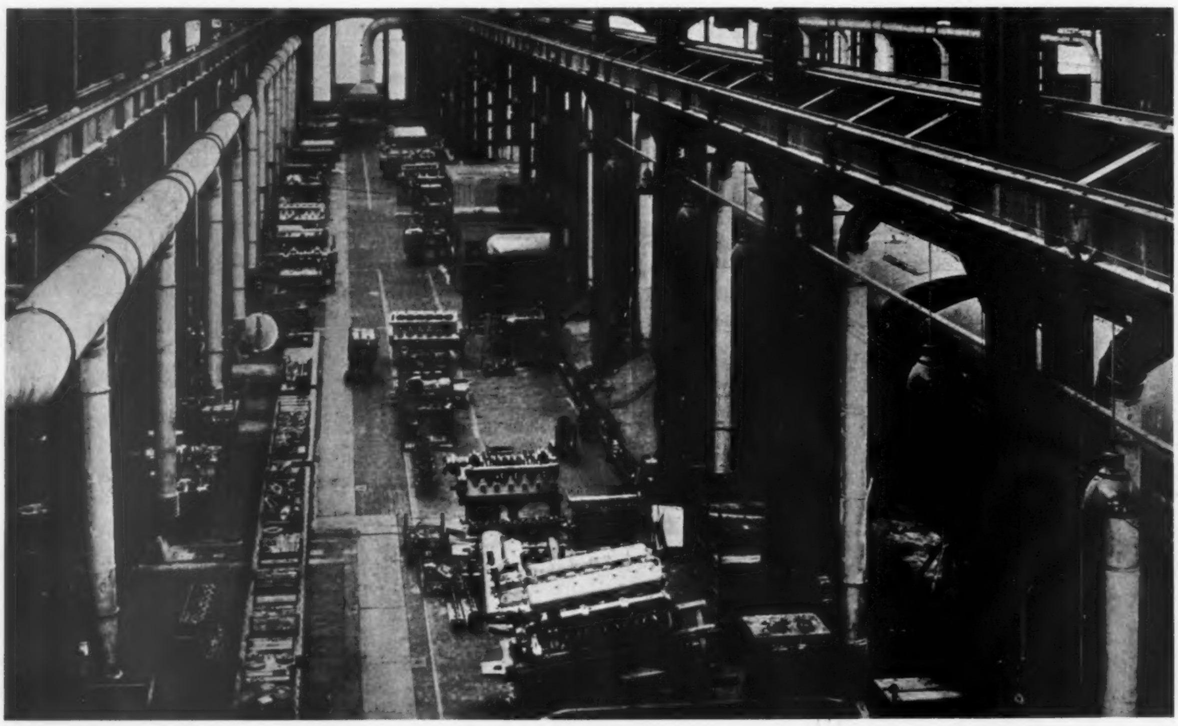
General inspection and adjustment of the connecting rods, with roller - bearing big-ends, of the Maybach 12 - cylinder vee engines, Haarlem works. A lime-wash process is being used to discover any cracks

small stations, which incidentally eliminated 1,800 train stops a day. In essence, this procedure abandoned light local traffic to the roads and concentrated on the semi-fast and fast medium and long-distance traffic.

As an example, the number of trains on the Amsterdam—Groningen line was increased from seven to 11, of which five were diesels, and the diesel time was reduced to 2 hr. 25 min. from the previous steam time of 3 hr. 25 min. Again, on the Amsterdam—Maastricht route the six old trains in each direction were replaced by 10 new fast trains, of which five were diesels running to an end-to-end time of 2 hr. 57 min. compared with 3 hr. 43 min. previously. The observed increase in traffic which followed this more intensive use of diesels to systematic timetables and faster and more convenient schedules, has come not only from road buses, but also from private car owners. Moreover, the reliability and characteristics of the diesel trains have enabled the quick interchange traffic at numerous junctions to be maintained in a satisfactory way.

Maintenance Methods

The general maintenance work on the diesel trains has always been centred at Utrecht, and as 90 per cent. of the trains have the same motive power and transmission, and all have the same design of mechanical portion, the con-



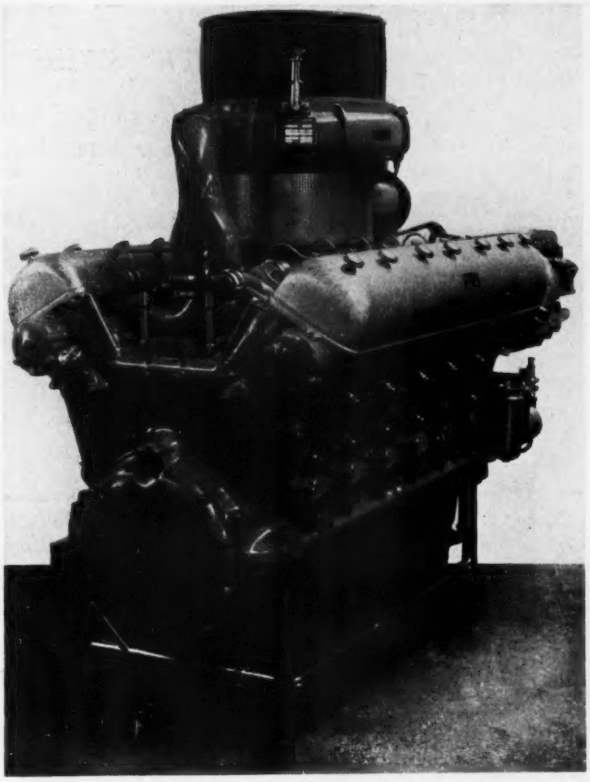
General dismantling shop at Haarlem, Netherlands Railways, used for periodic overhauls of the Maybach 410-b.h.p. 12-cylinder vee diesel engines

ditions for keeping up an adequate and economic maintenance service are of the best, and actually the time out of service for periodic inspections can be a minimum. By the connection of the engine cooling and car heating systems the trains need not be stabled under cover, even during cold weather, so that no special berthing sheds were necessary; by this and other small details, the initial expenditure on the diesel train depot was not unduly heavy, although the equipment includes fuelling, cleaning and light repair facilities, and a range of inspection pits and other equipment.

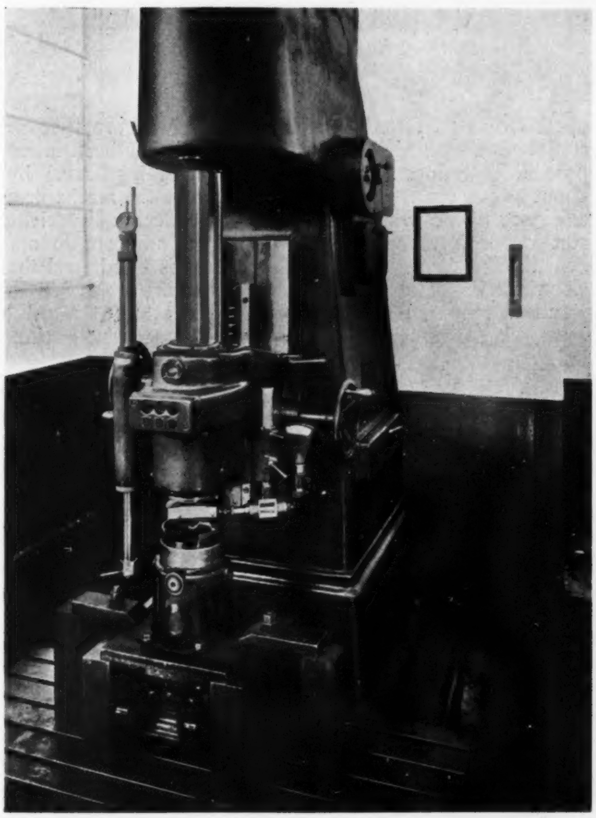
Main and intermediate overhauls are concentrated at the Haarlem works, where two of the eight 330 ft. by 27 ft. bays of the old steam locomotive shops have been rebuilt and equipped to suit diesel overhauls. Here, again, owing to the uniformity of motive power and car design, a quick and economical method of repair, based on a serial system, has been possible and the trains are returned to service quickly.

Engine Mileage

As far as the engines are concerned, the Maybach units at present are overhauled every 75,000 miles, which figure is based upon average requirements. A number of installations have run 85,000 to 95,000 miles between visits to Haarlem, and during the year 1938 the train-mileage per engine averaged 6,200 a month. Engines withdrawn from the trains are taken to an adjacent dismounting shop, where special fixtures and procedure have been adopted to give quick dismantling. From there the engine components are placed in boxes and carried along a roller conveyor to a cleaning tank. Thence they go along another conveyor to the inspection department, where each detail is examined and measured; it is here that the extent of the engine overhaul is decided. After adjustment, repair or renewal, the components are made up into group assemblies (*e.g.*, water, fuel and oil pumps), and after any necessary testing are transported to the erecting shop, where the engine is assembled. Finally, the working of the completed engine is checked over on the test bench, and a checking test is also given to the operation of the main components of the electric transmission. As the schedule maintained for the complete overhaul does not always allow track tests to be made on the electrical equipment after reassembly, an electrical testing station has been built to enable the electrical transmission to take up the full power of the engine with the train at a standstill, and for as long a time as may be desired, so that only a short test run is needed before the train is put back into service.



650-b.h.p. Maybach engine with Büchi exhaust-gas pressure-charger. This type of engine is being installed in 18 of the new Dutch five-car trains



Special boring machine for cylinder bores of the Maybach engines, Haarlem works

Italian Railcar Programme.—The Italian State Railways have recently ordered a further 100 diesel passenger railcars, each to be powered by two Saurer-type 150-b.h.p. engines running at 1,500 r.p.m., and built by the Off. Mech. Brescia, the Saurer licensee in Italy. These engines will operate through the Lysholm-Smith form of partial-hydraulic turbo transmission. The Fiat Company is building the mechanical portions at its Turin works. Fifty double-bogie cars with the same motive power and transmission, but with mechanical portions built by the Off. Mech. Milano, are due for delivery to the State Railways by the end of this year. Use of similar railcars, but with pressure-charged engines with an individual output of 225 b.h.p. is under consideration.

UP-TO-DATE SWISS DIESEL LOCOMOTIVES

Two pressure-charged units, for passenger traffic on standard-gauge lines, built throughout in Switzerland

The new Swiss locomotive for light passenger service

THE first of two medium power diesel locomotives for the Swiss Federal Railways has just been completed, and is now on view at the Swiss National Exhibition in Zurich; the second locomotive will be finished in two or three months' time, and will be turned over straight away to the railway authorities. Intended for the haulage of light trains, say from 180 to 200 tons, on fast stopping train schedules with end-to-end speeds of the order of 48-50 m.p.h. the new units are of the Bo-Bo type and have an installed power of 1,200 b.h.p.; they were built to the requirements of M. G. Steiner, Chief of Electric Motive Power, Swiss Federal Railways. The engine equipment was made by Sulzer Bros., the main electrical equipment by Brown Boveri, and the mechanical portion by the Swiss Locomotive Company.

With a service weight of 65 metric tons, they are probably the lightest diesel locomotives of such power which have been built, the unit weight being only 120 lb. per b.h.p. Multiple-unit control is incorporated, so that if occasion arises what is equivalent to a locomotive of 2,400 b.h.p. can be driven by one man. The bogies are of the type with inverted laminated bolster springs at the sides, and with the Friedmann axleboxes supported by two helical spring groups, one on each side of the box and connected by short compensating beams with the central points pivoting below the boxes. Welding has been used generally in the construction of the bogies and the body framing, which incorporates the floor and engine bed as a unit. Westinghouse brakes on the automatic and self-regulating principles are embodied, and the clasp rigging applies on each side of every wheel a double-unit shoe, comprising one cast iron shoe below the wheel centre line and one above. Such an arrangement should eliminate the distortion often found when very big shoes are used in conjunction with high pressures; further it has been found possible to reduce the required brake rigging travel by about 25 per cent., which tends to improve the mechanical efficiency of the whole brake gear. The electrically-driven compressor is mounted below the floor, adjacent to one bogie. The usual buffing and drawgear is fitted, and the electric train heating couplers at each end are of the S.B.B. standard type. A top speed of 110 km.p.h. (68 m.p.h.) is permitted, and no attempt has been made at streamlining.

Motive Power

Power is provided by a Sulzer 8LDA28 four-stroke engine, which in eight 280 m.m. by 360 mm. (11·0 in. by 14·2 in.) cylinders develops 1,200 b.h.p. at 750 r.p.m., giving a m.e.p. of 115 lb. per sq. in. and a piston speed of 1,780 ft. per min. The dry weight with all accessories and the welded steel underbed is 11·5 *tonnes,* equivalent to 21 lb. per b.h.p.

In order to have a design suitable for locomotives no attempt was made to obtain extreme lightness; on the other hand the weight of the engine had not to exceed a certain limit, in order that the comparatively low axle-load permissible on the lines where the locomotives will be used, could be maintained with the double-bogie wheel arrangement. Consequently the method of building up by partial welding was adopted. This has already been used successfully in a number of Sulzer locomotive engines, and comprises the welding together of small steel parts suitable for making good castings, and pieces of steel plate to form the crankcase and cylinder block. This construction, in comparison with the use of purely cast steel or cast iron,

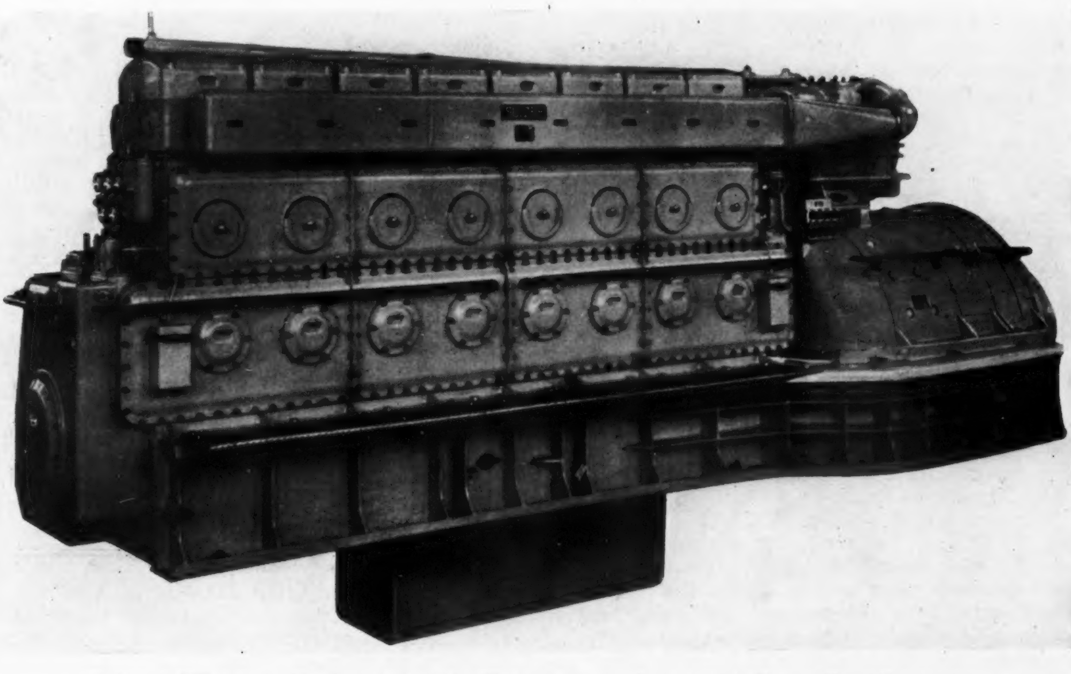
allows a much better utilisation of the material and consequently a reduction in weight, since all wall thicknesses can be maintained with great accuracy. In comparison with construction in light metal, this method has the advantage that the fatigue strength is not so far below the static tensile strength. Automatic lubrication of all moving parts is another feature, and as a result of this all moving parts have been enclosed and rendered dust-tight.

The crankcase consists of separate cast-steel cross-pieces carrying the bearings, with steel-plate longitudinal walls welded to the cross-pieces. The cross-pieces are connected to the outer walls of the crankcase through strong ribs, thus making the casing extremely resistant to any deformation through internal stressing due to the inertia of the moving masses. A welded steel subframe carrying the diesel engine and the generator set is connected to the crankcase by welding to form one single piece. All eight cylinders are joined together to form one cylinder block, and this also consists of separate cast-steel cross pieces and longitudinal walls of steel plate connected by welding. The camshaft is arranged within the crankcase, and the fuel pumps are mounted on a block in front of each cylinder. The pumps consist of Bosch elements in Sulzer blocks; they can be inspected easily at any time by removing the light hand covers inserted in the main cylinder block inspection covers.

Engine Construction

Each cylinder has a replaceable wet-type liner of special cast iron, which is held down in the block by means of the cylinder cover. The special carbon-steel crankshaft has nine bearings and is fitted with a dynamic vibration damper. The nickel-chrome steel connecting rods are of I-section, and the aluminium alloy pistons carry four pressure and two scraper rings. The hollow gudgeon pin of special steel is fixed in the piston and held in place by a secured key, and in the small end of the connecting rod, the piston pin is carried in a one-piece bronze bush. The camshafts carry the cams for the inlet and exhaust valves, and also the cams for the fuel pumps; camshaft and governor are driven by gearing arranged close beside the coupling within the covering of the crankcase. The arrangement of the fuel pumps immediately beside their own cylinders allows all the fuel pipes to be made of equal length, and the fuel pumps can be put out of service separately without stopping the engine. The fuel injection is direct, through a Sulzer nozzle placed on the centre of each cylinder head. Combustion air is led to the diesel engine from a Büchi exhaust gas turbo-blower pressure charger, which is supported on a frame above the main generator; the blower and turbine impellers of the set are fitted on the same shaft, which is fitted at each end in a roller bearing. The casing and the suction branch of the blower are built of light metal in order to reduce weight. Amply-dimensioned air filters are fitted in the suction air boxes suspended on the roof of the vehicle; these ensure not only good cleaning, but also very effectively a reduction of the noise made by the air drawn in. The turbine casing consists of special cast-iron and has water cooling, which is arranged as a by-pass in parallel with the cooling system of the engine. The blower supplies not only the combustion air, but also the air required for scavenging the cylinder at the end of the exhaust stroke. Consequently the times of opening of the inlet and exhaust valves of the working cylinders overlap, so that both valves are open together for a certain time and the air from the pressure-charging pipe can flow through the valves in the cylinder cover into the exhaust pipe, thus ensuring effective cooling of the valves and pistons, and also a reduction in the exhaust gas temperatures. The maximum allowable exhaust gas temperature is **550°** C., but in normal operation is appreciably less than this figure.

A gearwheel pump installed below the crankcase delivers oil from the oil sump into the forced lubricating system. Another pump arranged in the same manner delivers to the cooler the oil that flows back from this system into the oil sump. Normally the oil pressure is about **34** lb. per sq. in. at the bearing inlet and **37** lb. at the filter inlet. Excess oil from the rocker gear is led back into



Sulzer 1,200 *b.h.p. diesel engine with Büchi pressure-charger and Brown-Boveri generator*

the crankcase and sump down the inside of the push rod casings.

The cooling water is circulated by an electrically-driven pump with a 4.7 h.p. motor; the set automatically starts at the same time as the main engine; the cooling-water is passed through radiators arranged in the side walls of the locomotive, which are themselves cooled by a fan located in the roof. When the diesel engine is stopped, the pump continues to run for some time in order that the cylinder walls may be further cooled by the water circulating round them. When the pumping set is stopped, all water runs out of the cooler, thus preventing any risk of damage through freezing in winter. The cooler fan is driven by a vertical electric motor connected electrically direct to the auxiliary generator; the motor consequently starts as soon as the auxiliary generator is excited after the starting of the main engine, and it stops again when the engine stops.

Oil- and water-pressure contacts in the circuit of the electro-pneumatic stop valve cause the main engine to stop whenever the cooling-water or lubricating-oil pressures fall below certain predetermined values. In the same circuit there are two switches which break the circuit if the temperature of the cooling water or of the lubricating oil should exceed a maximum permissible limit; this safety device stops the main engine if the cooling fan runs too slowly or not at all, or if the thermostats that short-circuit the coolers when the oil- and cooling-water temperatures are low, do not function properly.

Electric Transmission

Because of certain special requirements the design of the principal generator group is unusual. As the Swiss Federal Railways desired single-phase electric heating apparatus for the train, so that standard carriages could be heated, a single-phase heating generator has been interposed between the main d.c. generator and the overhung auxiliary generator, this layout being preferred to the complication of an auxiliary diesel-generating plant to supply the heating load.

In accordance with modern Swiss requirements the main generator has been given two continuous ratings, one based upon the current and the other upon the voltage, for in the generator fields it is the voltage which is the limiting factor, whereas in the armature it is the current which governs the rating. The ratings are:—

Continuous			
High voltage	660 r.p.m.	650 V	1,060 A
Low voltage	660 r.p.m.	574 V	1,200 A
One-hour	660 r.p.m.	446 V	1,520 A
Maximum*	750 r.p.m.	820 V	2,300 A

* The maximum voltage and current are not obtained in conjunction with one another.

The auxiliary generator is overhung, and has a capacity of 35 kW; from the outer end of its shaft are the drives for the fuel priming pump and the engine tachometer. Between it and the main generator is the 100 kW single-phase $16\frac{2}{3}$-cycle heating generator with a rating of 1,000 volts 100 amp., and 30 volts excitation. Its voltage is kept constant whatever the engine speed by means of a voltage regulator, and the design of this generator is such that the brushes of the main d.c. machine can be seen from the end, and thus any sparking at the commutator observed. The engine barring gear is fixed neatly with teeth incorporated in the self-ventilating fan of the main generator. The starting winding of the main generator is fed from a 90-cell Jungner battery.

A steel partition plate extends across the locomotive at the back end of the main generator, and in the chamber between it and the partition plate of the adjacent driving cab is housed the single-phase heating generator, the auxiliary generator, contactor and control equipment, and a vertical motor-generator group which supplies current for the excitation of the heating generator and 36-volt d.c. for the control and lighting. Against the cab plate is also mounted a 2,000-litre (440-gal.) fuel tank. The fuel tank level indicator is mounted to the side; it does not give a permanent indication, but readings are given when required by pushing against a spring-loaded knob. In each cab are two 740-watt Therma heaters and an electric footwarmer located below a grille in the floor. The driving controls immediately in front of the driver are lighted by a single lamp fitted with a corona shutter, by which the light can be stopped down or allowed to flow through the full aperture of the lamp shield. Included in the controls is an ingenious but neat and simple power meter, which by the use of two pointers operating over a nomogram, indicates the current voltage and power at any time. The two pointers always cross at some point on the line corresponding to the controller notch in use, and a further check is given by track speed lines. A Teloc speed recorder is fitted on one side wall of the cab.

Control System

A nine-notch controller is fitted, and by this the driver sets the engine speed as required, and the governor keeps it constant by adjusting the quantity of fuel delivered. The governor also regulates the excitation of the main generator by actuating the servo-motor valve of the field regulating system. Between the governor and the linkage regulating the fuel pumps a spring member is fitted which prevents the governor from controlling the fuel regulation when the pressure-charging protecting device comes into operation. The latter consists of a servo-motor operated by the blower-pressure and acting on the linkage of the fuel pump regulation; this servo-motor makes the normal regulation free as long as the charging pressure, and therefore the combustion air available, is sufficient for the quantity of fuel as set by the governor. If the charging pressure is too low (for example at starting), the quantity of fuel is reduced to correspond to the amount of air available. In the case of a breakdown at the pressure-charging set, the protecting device also comes into operation. In the extreme case it is always possible to start without the charging set, in which case the protector, in conjunction with the diesel engine governor and field regulator, reduces the output to the value which the non-pressure-charged engine can give.

With the help of an air-controlled oil-pressure servo-motor the governor may be set for four different engine speeds. This speed adjusting device is controlled electro-pneumatically through the controller operated by the driver. The speed is graded for the various controller steps as follows:—

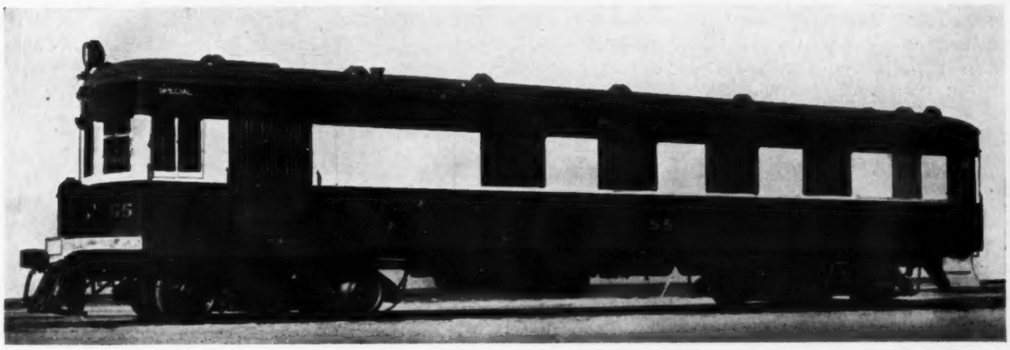
Controller Steps	Engine Speed, r.p.m.
0–4	450–430
5–6	570–560
7–8	670–660
9	750

With the governor linkage are also connected two air-operated pistons, one of which reduces the quantity of fuel injected at starting; the other serves for stopping the main engine and is designed in such a way that it makes the regulating linkage perfectly free when any compressed air is available, but stops the engine should the supply of compressed air fail.

BÜCHI PRESSURE CHARGERS.—There is now a total of 425 Büchi exhaust-gas turbo pressure-charging sets at work in, or on order for, diesel-railcars and locomotives, and they are fitted to engines varying from 140 to 2,200 b.h.p., and aggregating 265,875 b.h.p.

LONG-DISTANCE RAILCARS IN SOUTH AUSTRALIA

Four units show profit of 18d. a mile, after all charges have been met, over a 14-month period



Broad-gauge rebuilt diesel car to give comfortable travel on trips radiating from Adelaide

THE policy of utilising petrol driven railcars for light passenger services was first adopted by the South Australian Railways in **1923**. Cars seating **43** passengers were obtained for short-haul traffic, and soon afterwards larger trailer-hauling cars fitted out for long-distance travel were introduced. During the past few years, as the need to replace original power units has arisen, diesel engines have been installed in five of the smaller type and four of the larger type railcars of the early build.

The diesel engines fitted in the smaller cars comprise either a Gardner **5LW** engine developing **86** b.h.p. at **1,700** r.p.m., or a Gardner **6LW** engine giving **102** b.h.p. at **1,700** r.p.m., there being one car of **86** b.h.p. and five of **102** b.h.p. The four big rebuilt cars now have Gardner **8L3** engines giving **204** b.h.p. at the slower rotational speed of **1,200** r.p.m. Only the inner axle of the driving bogie is connected to the mechanical transmission, and it is provided with sanding gear having boxes located in the luggage room.

These last four big diesel railcars are allowed a maximum speed of **47** m.p.h. and are operated over **5** ft. **3** in. gauge lines on the wayside passenger services between Adelaide and Victor Harbour, Adelaide and Port Pirie, Adelaide and Gladstone, and Adelaide and Morgan, which have respective mileages for the return trip of **166, 272, 276** and **212**. One trailer car, accommodating **65** passengers with luggage compartment, is hauled throughout to the outwards terminal station, and two trailer cars over part of the journey from and to Adelaide.

Interior Fitting

The railcars have an overall length of **58** ft. **5** in., and seating accommodation for **53** passengers is provided in each of three; the fourth seats **34**. This last car, coincident with the installation of the diesel power unit, has been re-designed to conform to the high standard of comfort now obtaining in steam passenger services on country lines. Seats are arranged on the back-to-back principle and are finished in a pleasing tone of brown chrome leather with loose individual cushions supported upon a deep spring foundation, giving perfect and restful ease and eliminating the vertical movement often found with vehicles in motion. A full partition divides the smoking and non-smoking portions of the car, which are formed into semi-compartments by dwarf partitions extending about **4** ft. from the floor, thus ensuring ample protection against draughts from open windows. Large windows of armour-plate glass permit of an uninterrupted

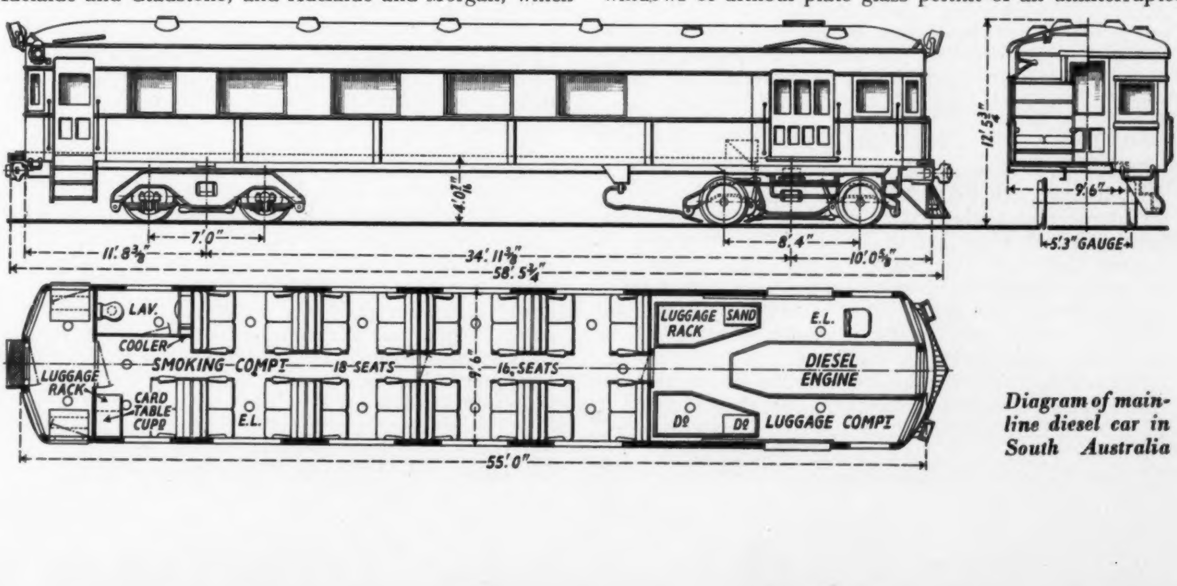


Diagram of main-line diesel car in South Australia

view of the countryside, and card tables, suitably housed in cabinets, are readily available for erection if desired. Modern lavatory accommodation is installed, and a drinking font with iced water is provided. The interior woodwork has a satin enamel finish of a maize shade and the ceiling is coloured a very light shade of Wedgwood blue. The exterior of the car is enamelled green and primrose relieved with black and red lines.

The first of the large type cars converted to diesel motive power was placed in service in November, 1937; the second in the following month, and the third and fourth in May and August, 1938, respectively. For the period of 14 months from November, 1937, to the end of December, 1938, these four cars brought in revenue aggregating £21,884, against which must be set operating charges amounting to £6,412, interest charges of £1,252, and depreciation £1,683. The profit per mile after making full allowance for operating, interest and depreciation charges, is thus about 18¼d. The mileage run was 163,991, and the equivalent passenger miles 4,805,778; trailer mileage totalled 167,319. Fuel consumption amounted to 30,348 gal., equivalent to 5·61 m.p.g.

EARLY DAYS IN DIESEL DEVELOPMENT

*By Dr. ALFRED J. BUCHI**

I MADE my first acquaintance with the diesel engine and its inventor, Dr. Rudolf Diesel, in 1898, when I was an apprentice at the Sulzer plant at Winterthur. In 1903 I went to Carels Brothers, in Ghent, which firm was famous for its steam and diesel engines. Their diesel engines were all small units, and operated with air injection of the fuel. Among the difficulties encountered with diesel engines at that time were that the air injection pump valves had to operate rapidly, and being similar to valves with conical seats they were too heavy. Later, dashpots were used to minimise the inertia forces, and after further experiments plate valves were used with greater success.

The piston crowns burned out as a result of the high m.e.p. and temperatures, and in an endeavour to overcome this problem a costly platinum plate was inserted in the centre of the piston head. After this engine had run some time it was dismantled, and it was then found that the platinum plate had completely disappeared. Most of the diesel engines built by Carels were sold to the coal country, England, and to that country's colonies.

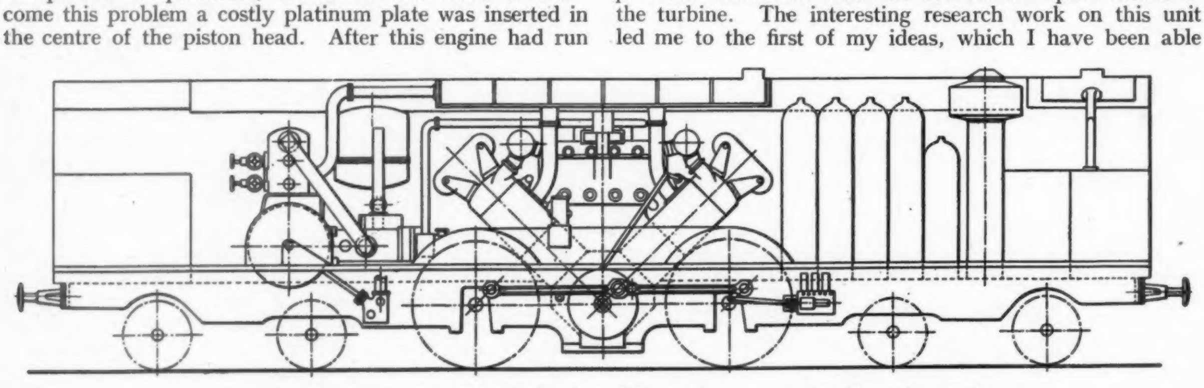


Diagram of Sulzer's pre-war 1,000-b.h.p. direct-drive two-stroke diesel locomotive

Vogt Engines

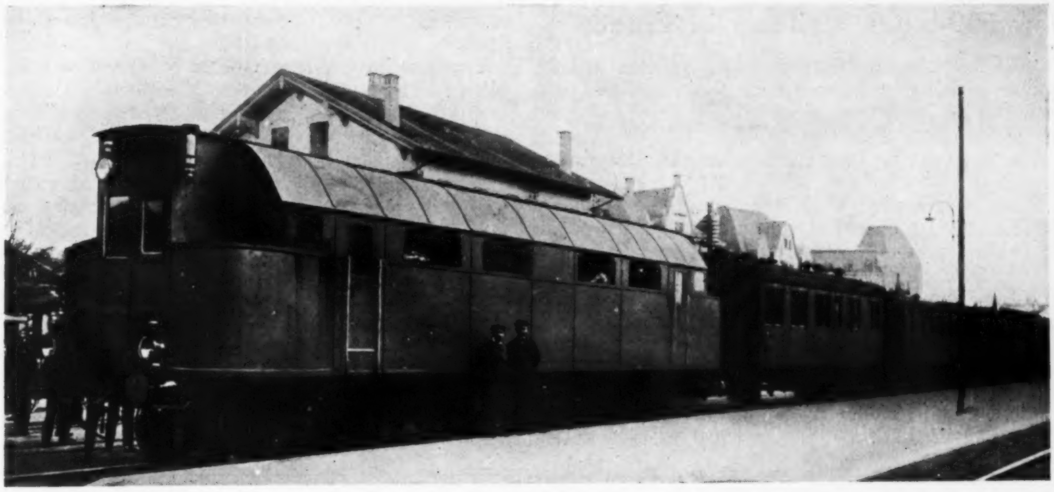
In the early years of this century, an Austrian engineer, Adolph Vogt, suggested that if the compression ratio of an internal-combustion engine could be changed and suitably adjusted according to the load and speed of the engine, the high compression would result in the best efficiency. I was asked to make the necessary drawings and carry out the tests. Vogt's first engine included, below the compression space, a small receiver which was filled with water during the suction stroke through a non-return valve. A spring-loaded overflow valve permitted the escape of a certain amount of water, depending on the pressure for which the spring was adjusted by hand or by the governor. When test runs began, and the pressure dropped during the exhaust stroke, the water in the receiver began to evaporate rapidly, and continued during the suction stroke, so that the cylinder barrel was partly filled with steam, and consequently the volume of fresh air and gas was considerably reduced compared with a normal engine. Another Vogt design was an internal-combustion water-column engine, but on account of the inertia forces of the water-column the test engine would not fire at a speed higher than 55 r.p.m.

Vogt's third proposal was a gas turbine, and in it he sought to overcome the effect of high temperatures on the turbine blading by adding the combustion air through a preheater combined with the combustion space ahead of the turbine. The interesting research work on this unit led me to the first of my ideas, which I have been able to follow up successfully to the point of using exhaust gases from a reciprocating engine to drive a turbine. By the initial expansion of the gases in the engine, the gas temperature is brought down to a reasonable and manageable figure.

After having ceased all diesel development work after a rather unsuccessful test engine in 1897-98, the firm of Sulzer Brothers again stepped into the field. Its chief engineer came to Carels, and through an arrangement obtained the designs of the Carels diesel engine. With the entry of Sulzer into diesel-engine building a period of strong and rapid development began. Besides the four-stroke engine for stationary work, Sulzer developed a two-stroke engine for marine purposes, and several firms, such as Burmeister & Wain and General Motors Corporation, have returned to something very like the original Sulzer two-stroke.

Diesel obtained his principal patents in 1892, but five years elapsed before an engine was running more or less successfully, at the Augsburg works of M.A.N. Dr.

* In an address before the Central Illinois section of the American Society of Mechanical Engineers



Sulzer 1,000-*b.h.p. direct-drive locomotive on test train in* 1914

Imanuel Lauster was the man who performed most of the early research on the diesel engine and put Dr. Diesel's theoretical ideas into practical and feasible shape. In 1907 and 1908 all the principal Diesel patents had expired, but the inventor continued his development work. Together with a company in Switzerland, he organised the Safir company, in Zurich, for the manufacture of small high-speed engines. The output of the models built was 5 b.h.p. per cylinder at 600 r.p.m., which was a remarkable speed for that time. The engines were not a great success, and the little high-pressure air-injection pump caused most of the troubles. Dr. Diesel lost a good deal of his fortune in this undertaking.

First Locomotives

Another of Dr. Diesel's ideas, worked out in conjunction with Sulzer, was to have a diesel engine coupled directly to locomotive wheels, and with a large independent compressor set to supply starting air. A 1,000 b.h.p. locomotive along these lines was built in 1913, but the war cut short the experiments upon it. Another proposal, made by Dr. Diesel and A. Klose, was to have a two-stroke locomotive engine provided with exhaust ports but no scavenging ports. After most of the burned gas had been exhausted, the remaining exhaust gas was compressed to about 570 lb. per sq. in., and then air, compressed in a separate compressor plant, was admitted with the fuel at about top dead-centre. In this way more air could be introduced into the engine cylinder than was possible with the standard engine. Ingenious means were taken to try and raise the temperature to the ignition value of the fuel, but without success.

Early Supercharging Experiments

About 1911, Sulzer made a test plant comprising a diesel engine, exhaust-gas turbine, and a pre-compressor to charge the engine. Tests were carried out with supercharging pressures up to 30 lb. per sq. in., with maximum cylinder pressures up to 1,450 lb. per sq. in., and with exhaust gas temperatures as high as 1,200° F. The tests proved that such an exhaust-gas turbine would work because the temperatures were not too high, and no corrosion or erosion of the turbine blading took place. Nor did the turbine choke up with the exhaust gases, even when they were smoky. But the Sulzer company did not continue the tests with this type of equipment.

An interesting test engine giving 2,000 b.h.p. in a single cylinder was built by Sulzer about 1912, and gave successful results, although some trouble was experienced with the pistons and the lubrication of the piston bearings. The cylinder diameter was one metre. Also in 1912, several 3,600 b.h.p. two-cylinder stationary engines were built at the Sulzer plant. One day while we were sitting in the drawing office the whole building began to vibrate. Everyone became greatly excited, thinking it was an earthquake. A second series of shocks, but much weaker, followed. Shortly afterwards the test engineer on the first of these 3,600 b.h.p. engines came into the office and told us that the vibrations were produced when the engine reached its normal speed. We had for the first time reached the critical speed produced through the resonance of harmonic actions of the rotating and oscillating masses coupled to the crankshaft and the power impulses in the different cylinders. We devised an instrument to measure the movement of each point on the shaft during one revolution. It was interesting to measure from the flywheel on the circumference of the shaft, which had a length of 45 ft. and a diameter of 16 in., a movement of one inch, which occurred six times during one revolution.

GANZ ENGINE STARTING.—The starting process used in the Ganz engine, which has been referred to more than once in these pages, is described in some detail in an article by Mr. H. G. Rhoden in the May issue of the *Metropolitan-Vickers Gazette.*

NEW ZEPHYR TRAIN SERVICE.—The 1,000 b.h.p. four-car stainless steel diesel-electric Zephyr train, *General Pershing,* went into regular service between St. Louis and Kansas City, over the lines of the Chicago, Burlington & Quincy Railroad, on April 30. It is the ninth Zephyr train of the C.B. & Q.

NEW YORK FAIR DIESEL EXHIBIT.—A twin-unit 4,000 b.h.p. Electromotive diesel locomotive, equivalent to two-thirds of one of the Seaboard Line locomotives illustrated and described in the issue of this Supplement for March 17 last, is being shown by General Motors Corporation at the New York World Fair. Weighing 250 long tons, and extending over a length of 140 ft., this machine was hauled over short temporary tracks from the unloading siding to its stand, and six days and an expenditure of about £400 were needed to move it the length of about five city blocks over boggy ground.

New 600-b.h.p. Railcars in France

THIRTEEN high-power double-bogie railcars are in course of delivery to the French National Railways, and will be used for trailer haulage principally on the lines of the Région du Sud-Ouest. Of the Renault ADX[2] type, they are powered by two Renault 12-cylinder (140 mm. bore by 170 mm. stroke) 300 b.h.p. engines mounted one above each bogie, and driving all wheels through four-speed mechanical transmission, which, with the top engine speed of 1,500 r.p.m., gives track speeds of 31, 55·5, 94·2 and 153 km.p.h. (19·2, 34·5, 58·5 and 95 m.p.h.). In normal service speeds in excess of 140 km.p.h. (87 m.p.h.) are not attained, which means that in top gear the engine is never running at maximum speed. The full-load full-speed fuel consumption of the engines is 200 gr. per b.h.p.hr., and the lubricating oil consumption under similar conditions about 8 gr. per b.h.p.hr. Enough fuel for a run of 800 km. (500 miles) is carried. The engine and transmission controls are operated electro-pneumatically.

The cars have a length of 26 m. (85 ft. 4 in.), a bogie pitch of 16·93 m. (55 ft. 6 in.), a bogie wheelbase of 3·0 m. (9 ft. 10 in.), and nickel-chrome steel monobloc wheels with a diameter of 850 mm. (33·5 in.). The car can negotiate at slow speeds curves of 80 m. (264 ft.) radius. The tare weight is 40 *tonnes* and the weight with full load 48 *tonnes*. There are leather-covered fixed seats for 64 passengers arranged in two saloons, a luggage compartment with emergency standing room for about 40 passengers, and two engine rooms and driving positions. The interior of the car is heated normally by the engine exhaust gases, but a supplementary hot-water system is brought into use during cold weather; the heaters are arranged along the bottoms of the side panels. Standard buffing and drawgear is fitted. Two 24-volt nickel-cadmium batteries, each of 410-amp.hr. capacity, are carried to cater for car lighting, controls, and engine starting.

Notes and News

Mylius Transmission.—Over 1,000 sets of Mylius mechanical transmission have been supplied, or are on order, for railcars and locomotives with internal-combustion engines. The powers range from 50 to 500 b.h.p. per unit.

New Argentine State Service.—On April 1 the Argentine State Railways began an express diesel service with a Ganz train between Buenos Aires and Rosario, *via* the Cordoba Central Railway. The time taken for the 190 miles is 4 hr. 15 min., inclusive of two intermediate stops.

Fast Trial in New Zealand.—One of the double-engined 260-b.h.p. bogie railcars of the New Zealand Government Railways recently ran from Wellington to Palmerston North, 87 miles, in 106 min., and on the return trip took 102 min. Speeds up to 70 m.p.h. were attained on straight sections of the 3 ft. 6 in. gauge track.

New Belgian Stock.—The Belgian National Railways are putting into traffic six new three-car diesel trains, and by the end of February, 1940, will have augmented their stock by a further 12 twin-car sets and six single-unit railcars. The six triple sets are each powered by two Maybach engines set to give 650-b.h.p. each with Büchi pressure-charger in operation.

Argentine Diesel Service.—Dating from January 1, the steam trains on the Puenta Alsina–Libertad line of the Buenos Ayres Midland Railway have been replaced by the 200-b.h.p. twin-car local-traffic diesel trains built by the Birmingham Railway Carriage & Wagon Co. Ltd., and described in the issue of this Supplement for October 28 1938.

American News.—The Ford Motor Company has ordered three 1,000 b.h.p. diesel-electric locomotives from the General Electric Company, each of which is to be equipped with two 500-b.h.p. Cooper Bessemer four-stroke engines. The existing 1,000-b.h.p. locomotives at the Ford plant were fully described in the issue of this Supplement for November 25, 1938. The Chicago, Milwaukee, St. Paul & Pacific Railroad has entered into lease-purchase contracts for two 1,000-b.h.p. and two 600-b.h.p. Electromotive diesel locomotives for use at Milwaukee, and for two Alco 600-b.h.p. locomotives for use at Cedar Rapids, Iowa. The Wabash Railroad has recently contracted for four 600-b.h.p. diesel-electric switching locomotives. The Chicago, Rock Island & Pacific Railroad has been enquiring for two seven-car streamlined trains, each to be hauled by a 2,000-b.h.p. diesel locomotive.

Peruvian Railcar Order.—The Peruvian Corporation Limited has placed with D. Wickham & Co. Ltd. an order for five standard-gauge double bogie railcars, four of which will nominally be operated in two pairs. The power unit of each vehicle is to be a Saurer BXD six-cylinder engine pressure-charged on the Büchi system to give 200 b.h.p. at sea-level and 160 b.h.p. at 15,000 ft. at the normal top speed of 1,500 r.p.m. The transmission is to comprise a Vulcan-Sinclair fluid coupling, Hardy Spicer cardan shaft, and Cotal epicyclic electromagnetic gearbox. Two of the cars are to have accommodation for 50 first class passengers and two will seat 74 second class passengers.

Publications Received

Fluid Couplings.—The evolution of fluid drive, as exemplified by the Vulcan-Sinclair forms of fluid coupling, is well illustrated and described in a beautifully-produced brochure just issued by the Hydraulic Coupling & Engineering Co. Ltd., of Isleworth. The characteristics and operation of the traction and scoop-controlled types are described with the aid of graphs and coloured sectional drawings, as well as by illustrations of the constituents. That section dealing with the variety of applications includes several railway installations, and in particular there is an impressive illustration of 14 Carels-Ganz engines, with a maximum output of 380 b.h.p., to each of which is fitted a Vulcan-Sinclair traction coupling; these couplings form part of an order for 30 for the Belgian National Railways.

The Modern Diesel. Fifth Edition. London: Iliffe & Sons Ltd., Dorset House, Stamford Street, S.E.1. 7½ in. by 5 in. 248 pp. Illustrated. Price 3s. 6d. net.—This book deals solely with the high-speed small and medium-power oil engine and in its appeal appears to be intended principally for the road transport engine user, although there are chapters on railway, aircraft and marine engines. The 15-page railway section, like the remainder of the book, has been properly revised, and gives a balanced review of the extent to which diesel traction has been adopted in various countries and of the different engine makes which are used. In the road section the features of numerous English and Continental makes are described, and there are comprehensive chapters on combustion chamber design and fuel injection systems; a selection of auxiliaries is covered in a useful chapter on the diesel chassis. There is also a note on the early development of the oil engine, which seeks to give Akroyd-Stuart his due, and the rightful credit, for later work, to such men as Mr. A. E. L. Chorlton.

Diesel Railway Traction

Diesel Train Auxiliary Loads

THE auxiliary loads of American high-speed diesel trains —cooking, lighting, air-conditioning, and so forth— are rising to such unmanageable proportions that on its latest Zephyr train, *General Pershing*, the Chicago, Burlington & Quincy Railroad has adopted a new arrangement by installing a separate auxiliary power plant on each vehicle, although the train itself is composed only of four cars including the main power plus baggage car at the head end. Mounted in a sound-deadening box beneath the floor of each of the three passenger cars is a 70 b.h.p. Hercules oil engine running at a top speed of 1,800 r.p.m. and connected directly to a General Electric three-phase 220-volt generator of 30 kW capacity. This set supplies power for all the requirements of its car except the braking air, which comes from a compressor in the power car. Although the cars are normally quite separate as regards their auxiliaries, three-wire train lines and jumper connections are provided so that in the event of an auxiliary power plant failure a car can be supplied from the adjacent vehicle. This power plant appears to be more than ample, for the maximum demand under the worst weather conditions does not exceed 31 kW per car. Only a portion of the car heating comes from the three-phase generator, the remainder (two-thirds to three-quarters) being supplied by the auxiliary engine cooling water. Beginning at 45° F., a small amount of electric heat is used, and varies from 5 kW as a minimum to 20 kW as a maximum per car. The exhaust manifold of the oil engine is water-jacketed in order to give sufficient heat from the water system during cold weather. The water flows over an electric immersion heater which not only supplies heat to the car, but can heat the car under stand-by conditions, and heat the engine water system to give an easy start in cold weather.

Remote and Automatic Controls

REMOTE and automatic control of railcars with mechanical transmission has been gradually evolved over a number of years, and although there are several forms of remote control working satisfactorily, the development of fully-automatic control, in conjunction with multiple-unit operation when required, is still a stage behind. More than one operating aspect of automatic control awaits a proper solution, but the main disadvantage of any form of remote, semi-automatic or fully-automatic control is increased maintenance. Even with ordinary single-unit cars having one or two engines and mechanical transmission, the auxiliary apparatus (more especially electrical) invariably accounts for the greater part of the time spent on maintenance if the design of the car and motive power equipment is reasonably good, and the addition of over 30 control wires down the car or train, as required by the Mylius automatic control in its present state (and including car auxiliaries) is not likely to ease the position. Of other types of remote control, the Renault requires 16 cables and an air pipe to be run down the train for one engine per vehicle, and the De Dietrich system, with two engines per car, requires 15 cables and four air pipes, but in neither of these examples is the control automatic or semi-automatic. With electric transmission the controls to ensure the synchronisation of the speeds of the engine-generator groups are fairly simple, and in a certain type of car with two engines there are only eight wires down the train. On single-unit gear-drive cars, even with two engines, it is not a difficult matter for the driver to synchronise the operation of the two clutches, but with two or more cars coupled in multiple-unit, synchronisation of the mechanical clutches is much more difficult, as the driver may not always be aware immediately of any defects in operation or synchronisation. It is not easy to ensure perfect matching of the fuel injection and clutch engaging and disengaging controls down a train of power cars, but on the degree of perfection attained and maintained depends a good deal the time spent out of service, for it affects not only the transmission and the controls, but also the mechanical portions of the cars.

Two-Stroke Engines

SURPRISE is often felt at the small application of two-stroke engines to traction duties, particularly in view of the requirements of high power per unit of weight. Despite twice the number of impulses at any given speed, the two-stroke of equal cylinder dimensions and speed does not give anything like twice the power of a four-stroke. The incomplete scavenging which is possible in the short time available prevents the attainment of equal m.e.p.s. and moreover prevents the general run of two-strokes turning at the rotational speeds considered quite normal for railcar four-strokes. Since the abolition of the piston valve controlling the exhaust, and its replacement by a single poppet valve in the head, the speed of the Burmeister & Wain type of railway two-stroke has increased to 1,250 r.p.m. as a maximum, but the Winton engine, most used of all, is still limited to 750 r.p.m. The Junkers opposed-piston type of two-stroke, on the other hand, has been operated for years at 1,500 r.p.m., and the newest models have a power-weight ratio well below 10 lb. per b.h.p.—better than most of the pressure-charged four-stroke engines. All the ordinary railway two-strokes—which in makes are limited to the Winton and Burmeister & Wain—have uniflow scavenging, with inlet ports round the liner and an exhaust valve in the cylinder head, and are thus in contrast to the majority of two-strokes for industrial and marine purposes. It is this attribute of the opposed-piston engine which has enabled the speed and output of the normal two-stroke to be increased during recent years. As in two-stroke engines the inertia forces are cushioned by the compression, high piston speeds can be used in conjunction with moderate rotational speeds, and with cast iron pistons; for example, the Burmeister & Wain type of engine running at 1,200 r.p.m. has a piston speed of 1,735 ft. per min. Heating of the piston crown and the underside of the cylinder head is the weakest point in the practical operation of two-strokes, because combustion occurs once every revolution, but mechanical considerations may be a limiting factor, *e.g.*, the cylinder pressure acts uniformly downwards, and requires special attention to be given to the bearing lubrication system.

REMOTE-CONTROL OF MECHANICAL TRANSMISSION

Descriptions of two new types of multiple-unit equipment designed to suit different classes of gear drive

THERE are at present in service two basically different types of mechanical transmission; the first fitted with a multi-plate or special type of clutch for each gear step, *e.g.*, Ganz, Renault, S.L.M.-Winterthur, and Ardelt; the second provided with a single main clutch common to all gear steps and having pre-synchronising control, *e.g.*, the Mylius and Wilson types, or with two clutches, such as the Minerva transmission. With either type a reliable form of remote and multiple-unit control is desirable, so that full operating advantage can be taken of railcars having gear drive. Among the forms recently introduced is one applied to the 250 b.h.p. double-engined car with Ardelt gear (that is, to a transmission of the first group) on the Niederbarnimer Railway, and another fitted to several high-power Mylius gearboxes (second group).

Ardelt Control Scheme

In Fig. 1 is shown the simplified control scheme of the Ardelt-equipped car on the Niederbarnimer Railway; the connections for starting, engine speed, water temperature and oil pressure are not included in the diagram. Each of the gearboxes is provided with four magnet valves for the admission of air for operation of the various gears. The car is started by the driver in turning the selector switch to position *H* or *A*, corresponding to hand or automatic gear operation, the selector switch being also used for car reversing as well as to switch out the entire controls of a driving position. In placing the selector switch into the *H* position a relay *10* is energised by the battery over wire *9*, the gear controller and wire *8*, and this in turn actuates the switch *11*. The driver now presses down the dead-man handle on the controller and turns it into the first step; thence over wire *1* switching in the contact ring *12* and *13*, and a rotary switch *14*. The switchgear is now turned by the motor *15*, the switch *14* energising the first gear magnetic valves of both transmissions. At the same time the insulating distance piece between the rings *12* and *13* is turned from contact *16* under the brush *1* which interrupts the current to motor *15*.

The same cycle is repeated as soon as the driver turns the controller handle into the next step, thus energising wire *2* and switch *14* operating the magnet valves of the second gear. The motor *15* is again cut out by the distance piece being turned so as to come under brush *2*. Should the controller handle be moved backwards from second to first gear this operation will switch in brush *3*

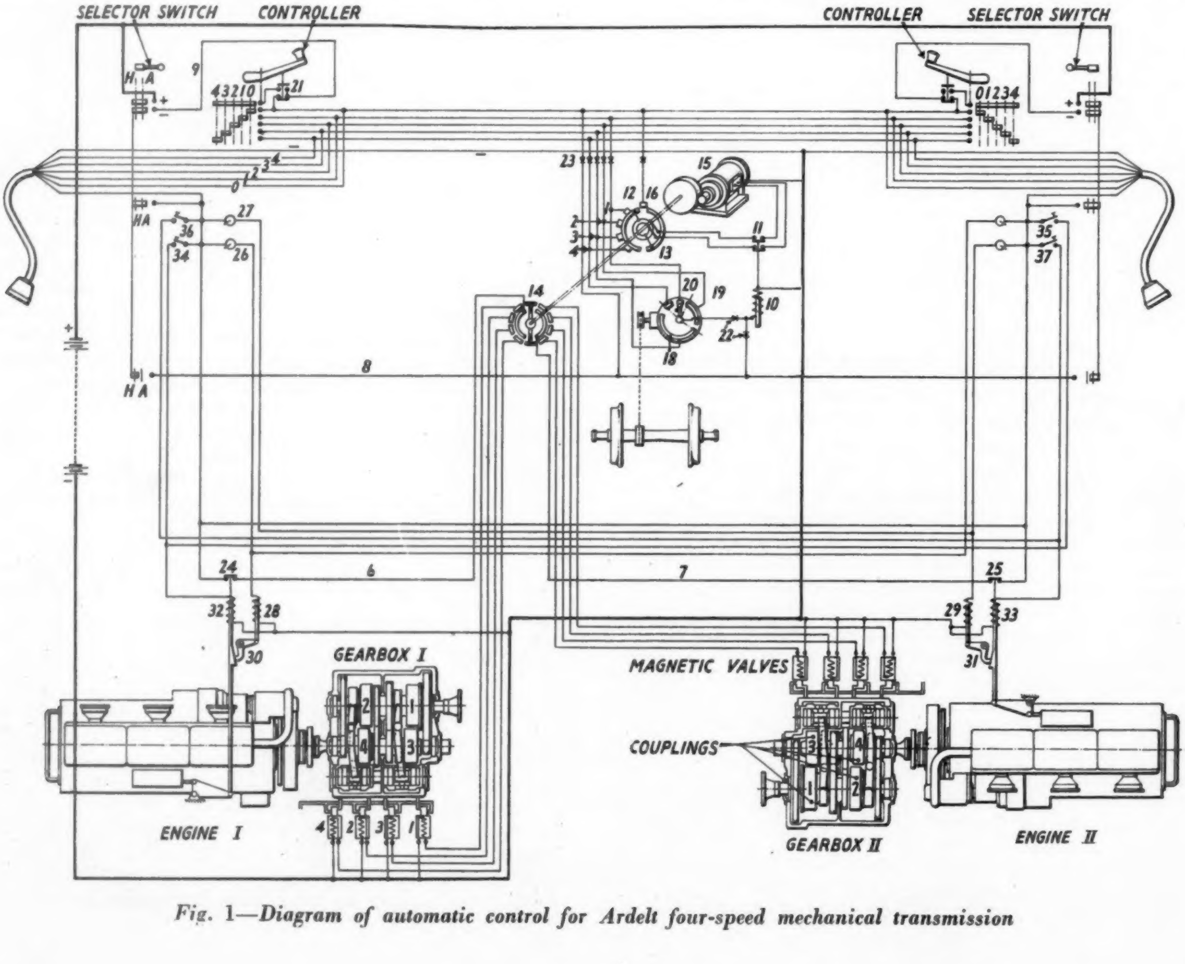


Fig. 1—Diagram of automatic control for Ardelt four-speed mechanical transmission

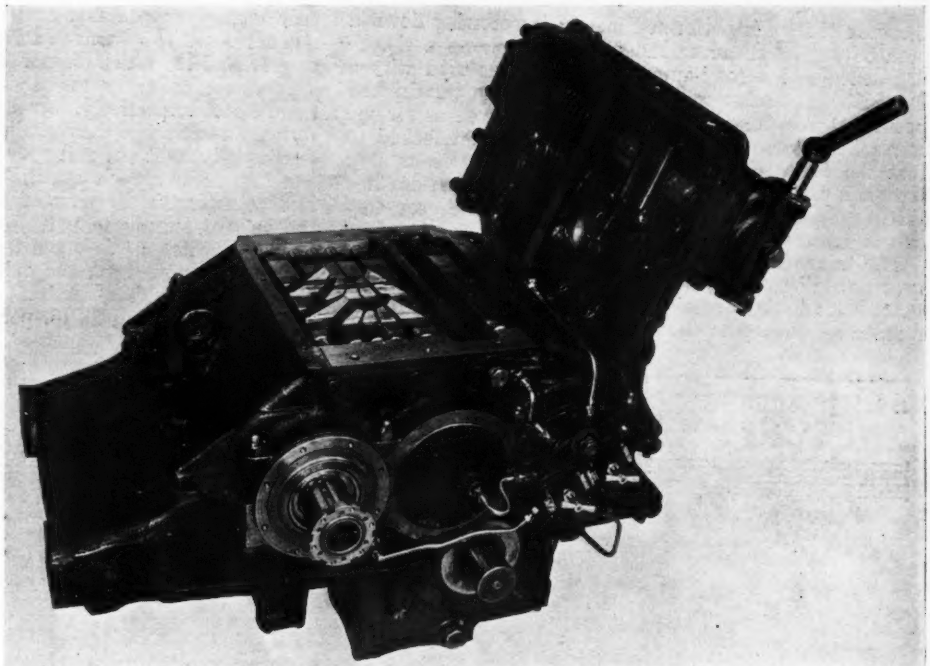


Fig. 2—350-b.h.p. Mylius five-speed gearbox with double-end drive; cover lifted back to show gear-changing rods. Either semi-automatic or fully-automatic remote control can be fitted to boxes of this type

and reverse motor *15*. The dry cell rectifiers *22* and *23* are employed in a way that ensures the passage of current in one direction only. While the current to the operating valves of the first transmission is supplied from switch *14* by wire *6*, wire *7* is used for the second unit. To stop an engine, the corresponding transmission is disconnected from the control system by the contacts *24* or *25* respectively.

Fully automatic control is obtained in turning the selector switch into the *A* position, in which case both the relay *10* and contact *11* are actuated by means of an axle-driven contact speedometer *18*, shown on the diagram with the car at a stop. In this case the finger *19* touches the contact *20* connected to wire *1*. The controller handle can be turned right into the last position, the wire *4* being energised after pressing down the dead-man handle, and thus closing the switch *21* and in turn connecting the battery with brush *4*, and contact ring *12*. The brush *1* now actuates the relay *10 via* contact *20* and finger *19* of the speedometer, which touches contact *11*. The car now starts, and with the increase of speed the speedometer hand moves clockwise. The finger attains position *1* as soon as the car reaches a speed corresponding to that at the top of the first gear. Here the finger *19* touches contact *22*, which is connected to the ring *12* by means of brush *2*, thus energising relay *10*, and switching in the operating motor *15*, which in turn actuates the second gear. The motor is now in operation till relay *10* is switched out by the insulating piece between *12* and *13* being turned under brush *2*. A similar operating cycle is repeated as soon as the car speed becomes equal to that attained at the top of second gear, and so on until the top gear is employed.

Both transmission units are interconnected with their engine starters by means of switches *26* and *27* respectively. In starting engine *1* the switch *26* actuates the releasing coil *28*. This releases the locking device *30*, which in turn places the fuel injection pump control rod into the engine running position. This rod is connected to the solenoid coil *32*, thus closing contact *24* and energising wire *6*. Should it become desirable to put engine *1* into operation while the car is running, the desired gear can be employed *via* wire *6* and rotary switch *14*. The engines can be stopped with the car in motion by moving the rod of the injection pump by means of solenoids *32* or *33*, which are actuated by means of switches *34* and *35* respectively. The current supply for gear control is then interrupted by the switch *24* while the solenoid *32* is held in position by the locking device *30*.

With the arrangement described, the current for operation of the gear control valves, operating motor *15*, engine stopping solenoids *32* and *33*, and the release coils *28* and *29*, is supplied by the battery of the leading car. In case of automatic operation, the transmission of any car is controlled by its own speedometer entirely independent of the other units of a train, as the speedometer contacts are individually adjusted so as to ensure the best operating results in obtaining maximum acceleration.

Mylius Semi-Automatic Control

A complete description of the latest high-power type of the Mylius gearbox and transmission was given in the issue of this Supplement for July 9, 1937. A multi-plate friction main clutch is used, and pre-selective synchronised gear-changing is effected pneumatically through the medium of cone clutches. With manual control the gear change is effected in pre-selecting the gear desired and then engaging it by gradually admitting air through the driver's control valve into the gear-change operating cylinder, fixed at the gearbox cover and common to all gears.

The main clutch is disengaged by increasing the cylinder pressure to about 28·5 lb. per sq. in., while a further increase up to 42 lb. per sq. in. results in the disengagement of the running gear. The gear to be engaged is synchronised as the pressure is increased up to 70 lb. per sq. in. The synchronised gear is engaged in reducing the air pressure to about 42 lb. per sq. in., while the main clutch is engaged by a further reduction to about 28·5 lb. per sq. in.

With manual control, the driver had to pre-select the gear desired, throttle the engine, admit air into the operating cylinder, let air out of the cylinder and bring the engine to full speed; with semi-automatic control, however,

the gear change is performed merely by pressing down a push-button. The accompanying Fig. 3 shows a simplified scheme of a semi-automatic control, as used with a five-speed transmission. The push-buttons at the driver's position *1* are provided for each gear, as well as for the transmission disengaging position, and are interlocked so that the engaged button is released as soon as another button is pressed down. This prevents more than one line being energised at a time, and thus only one gear step can be engaged at a time.

The transmission is shown with all gears in neutral, the gear operating rods and interlocking contacts *6* of the five gears being in the central position. The gears are synchronised when moved to the left, and engagement is effected when moved to the right. The contacts are interrupted only when the gear is engaged. The rods *6* are operated by the pre-selecting spring drums *14*, but as there is no rod for the opposition, the wire concerned is disconnected by the switch *29* operated by the left drum of the two drums marked *14* in Fig. 3.

The gears are pre-selected by means of an air cylinder *9* working against the pressure of a smaller cylinder on the left permanently connected to the air supply. The larger cylinder is controlled by the magnetic valve *8* and when actuated pushes a race to the right, thus turning the gear-pre-selecting shafts *10* and *13* into the desired position. As soon as the air exhausts from the main cylinder, the race is pushed to the left, thus pre-selecting the O-position. The pre-selecting gear is provided with locking solenoids *7*, which are applied by the push-buttons of the gear concerned, and in being pulled down actuate the magnet valve *8*. This results in the race and shaft moving to the right against the solenoid lowered lock of the gear concerned, which is now pre-selected. There is no locking solenoid for the fifth gear, the control wire of which is connected directly to the valve *8*. In pre-selecting the last gear the shaft is pushed against a fixed terminal lock. After the gear is pre-selected, current is switched in to the gear change apparatus by the switch *12*, energising the magnet valve *16*, which in turn admits air into the cylinders *17* and *18*, which disengage the gear in operation and synchronise the gear to be engaged and disengage the main clutch respectively. At the same time, air is admitted through a valve into the container *19*. Here the air pressure is gradually built up, and after the gear has been synchronised, the valve *20* is opened against the spring pressure and actuates the air-operated switch *21*. This interrupts the current supply to valve *16*. The piston *20* ensures that the switch *21* is opened during the time the air is rapidly escaping from the cylinders *17* and *18* into the container *22*, with a resultant pressure drop from 70 lb. per sq. in. to about 28 lb. per sq. in., thus engaging the gear as well as slowly engaging the main clutch. The air now escapes from the container *22 via* the valve *23* and magnet valve *24*, which results in the final engagement of the main clutch. The valve *24* is closed when engaging the first gear only, in order to ensure a gentle engagement of the main clutch in starting, the air from container *22* now escaping through valve *23* only. The current consumption of valve *17* is 0·6 amp. at 24 volts.

The engine speed is governed from the driver's position by the pressure reduction valve *25*, the fuel pump being actuated by the cylinder *31*. As long as the main clutch is disengaged air is admitted to the control valve *32*, which connects the cylinder *31* with the exhaust line, thus throttling the engine. The operation of the O-step is effected in pressing the push-button concerned, and as the O-step is always pre-selected, current is sent to the operating apparatus *via* contact *29*, disengaging the main clutch as well as the gear engaged. The left spring drum *14* is released from the rod of the disengaged gear, swings into the O-position and interrupts the contact *29*, thus engaging the O-step. Relay *V* disconnects the gear pre-selecting mechanism, which if under push-button control only would prevent the application of the O-step. The relay *26*, which has a current consumption of about 0·6 amp. at 24

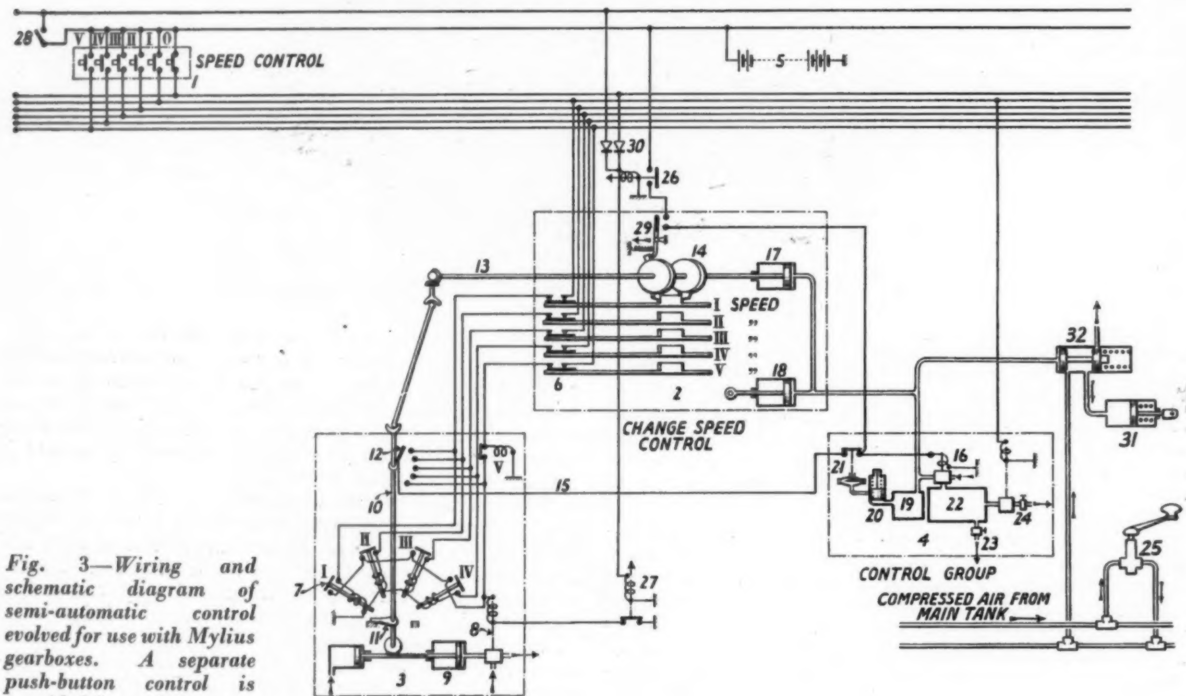


Fig. 3—Wiring and schematic diagram of semi-automatic control evolved for use with Mylius gearboxes. A separate push-button control is provided for each gear step

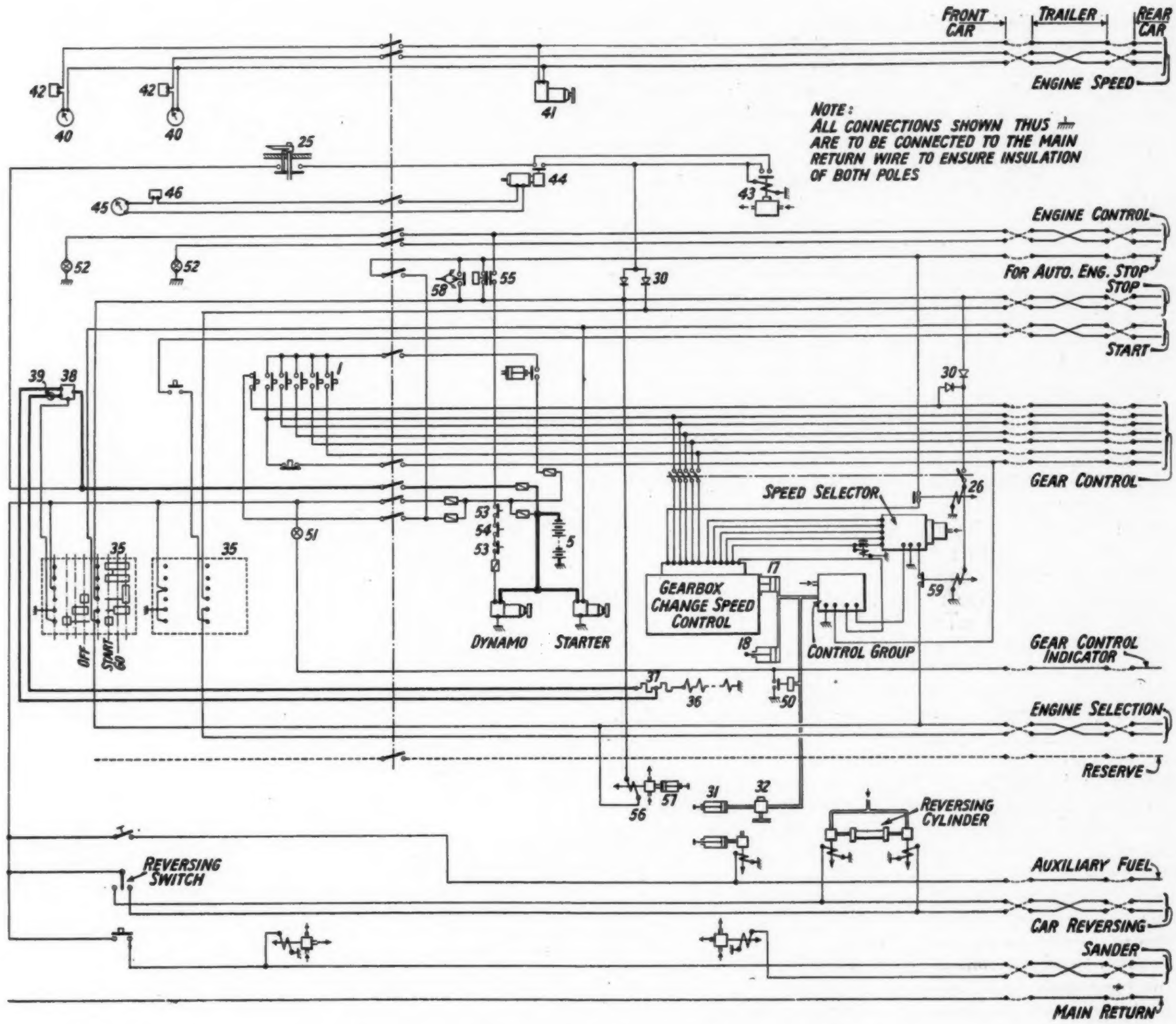


Fig. 4—Wiring diagram of fully-automatic control, on the contact-speedometer principle, for Mylius mechanical transmission

volts is provided for feeding the O-step control circuit, while the two dry-cell rectifiers *30* ensure a foolproof connection of current supply when connecting several cars.

Mylius Fully-Automatic Control

A fully-automatic control along similar lines can be provided in replacing the push-button control by a contact speedometer. The complete control scheme shown in Fig. 4 was developed for a train comprising two single-engined cars with a trailer between, as recently delivered to the Sorocobana Railway and described in the issue of this Supplement for December 23, 1938. With this train the control equipment of each power car comprises the push-button-operated change-speed control, speed selector and control group. Two master switches, *35*, one for each engine, are provided at each driving position. In the engine starting position these switches connect the engine heating plugs *36*, over a resistance *37* to the battery *5*, *via* the switch *38*, a control lamp *39* being also provided. The speed of each engine is shown by the rev. counters *40* energised by the dynamos *41* over an adjustable resistance *42*. The engine throttle control handle *25* incorporates dead-man's features in applying the brakes by actuating the valve *43*. The engine is stopped by valve *56* applying the stop cylinder *57*, while the gear control is cut out by switch *59*. However, the brakes are applied only should the driver remove his hand from handle *25* when travelling over a certain speed which is set by an adjustable contact at the speedometer *44* which feeds the speed indicator *45* at the driver's stand *via* the adjustable resistance *46*. The sequence of the gear engagement is indicated by the lamp *51* operated by switch *50*; the temperature of engine cooling water and lubricating oil, water level and oil pressure are indicated by lamps *52* energised by switches *53, 54* and *55* respectively. The engine is also protected from excessive speed by centrifugally operated switch *58*.

Reversing is effected electro-pneumatically, the reversing switch handle at the driver's position being arranged so as to permit operation only in pulling out a locking button, an operation that requires both hands. This device, together with the dead-man mechanism incorporated makes reversing possible only when the car is stationary. As indicated, a total of 34 wires are to be run *via* jumper connections through the train, this being perhaps not an excessive number considering the fact that in it are included

wires for auxiliaries such as engine heater pumps, sanders, and reserve wire. Current is supplied by a 24-volt storage battery, all connections between the cars being effected by a single coupling, the socket of which is about 7 in. in diameter. This coupling is arranged to ensure disconnection without any damage in the event of breakage of the main coupling of the car.

Contrary, however, to fully-automatic control as used with electrical or hydraulic transmission, there are still several difficulties to be solved with automatic control when applied to mechanical transmission. The control operating speedometer may be somewhat sluggish in action, and the provision of a centrifugal type of regulator for gear control may be found advisable. Both types of control apparatus are wheel driven and should the drive be taken from the driving wheels an occasional wheel spinning would result in a rapid engagement of all gears up to the top one. On the other hand, should the control operating mechanism be arranged for a drive from the trailing wheels, an occasional wheel slip when applying the brakes while rounding sharp curves would result in the engagement of the bottom gear, or disconnect the drive altogether, with a resultant series of jerks in quickly engaging the gears as soon as the wheels are released. A further difficulty is found when travelling over gradients, the resultant tractive resistance of which, although being below the tractive effort developed at a certain gear, is well above the tractive effort developed at the next gear. Here the control apparatus would automatically engage the next gear upon reaching at point *a* (Fig. 5) the top speed of the gear engaged. As the gear change is not effected instantaneously, the car speed would drop to point *b*, and as the tractive effort developed at the gear now engaged is insufficient, a further drop to *c* would occur. In the meantime the wheel driven control apparatus would fall back and engage the preceding gear, with a consequent speed reduction to *d*. The car will now accelerate again to *a* and the whole cycle repeat itself until the grade is passed or the automatic control is cut out. Although not insurmountable, the difficulties mentioned still exist at the present stage of development.

With the requirements for less weight and space becoming increasingly important, the control equipment has been designed to meet both needs. While the Mylius gear selector apparatus can be accommodated within the space of 18 in. × 13 in. × 9 in., the gear and main clutch control group requires a space of 25½ in. × 14 in. × 11 in. The weights are about 65 and 82 lb. respectively. As the weight of the 300 h.p. type E five-speed gearbox, complete with main clutch, is about 1,600 lb., the increase in weight will be about 10 per cent. and 12 per cent. with semi- and fully-automatic control respectively.

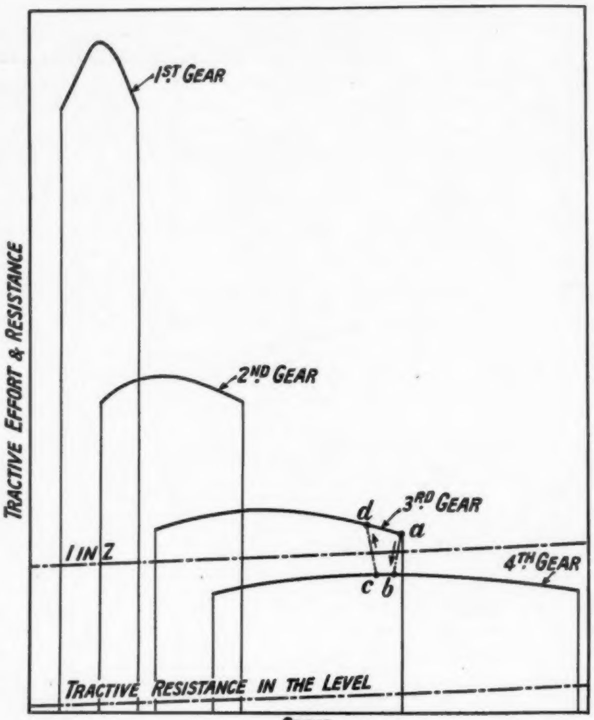


Fig. 5—Variation in tractive effort and track speed with certain types of fully-automatic control

While at present both the semi- and fully-automatic control equipments have reached a stage of thoroughly reliable service, it is the fully-automatic equipment that may gain ground, as in the field of electric traction, for it has the advantage of relieving both driver and power equipment from unnecessary strain. It should also considerably reduce the maintenance expenses.

There is, however, still much to be desired in the simplification of the control layout. The whole control apparatus should be assembled into a single unit, interconnected by as few wires as possible. The various interlocking devices should be of the utmost simplicity, as it is usually these parts which make the location of failures so difficult in the case of breakdown. Further, the control should be designed along either "all-electric" or "all-pneumatic" lines, as a combination of both makes repairs and maintenance considerably more difficult and expensive.

Snøggtog

THE Norwegian State Railways have ordered for the Oslo—Bergen and Oslo—Trondheim express passenger services four three-car diesel trains, thus bringing to fruition the developments we foreshadowed in the issue of this Supplement for February 17 last. The train sets will be composed of three non-articulated carriages seating a total of approximately 160 passengers, and there is to be a power plant and a driving compartment at each end of the train. The estimated weight is about 170 *tonnes* and the top service speed is to be 110 km.p.h. (68 m.p.h.); a speed of 48-50 m.p.h. up the 1 in 50 grades is anticipated. On each end bogie of the train will be carried a Maybach 12-cylinder vee engine equipped with a Büchi exhaust-gas pressure-charger and set to give a maximum of 650 b.h.p. at 1,400 r.p.m.; it will drive a hydraulic torque converter. The construction of the mechanical portions is to be principally in light aluminium alloys. It is understood that the contract price for the four trains, which are to be built by the Strømmens Verksted, is about £180,000. These trains, which are to be named the Snøggtog, will have about 7·5 b.h.p. per ton of weight and an approximate weight per seat of one ton. It is hoped that with these diesel train sets a schedule of 7¼ to 7½ hr. will be possible between Oslo and Trondheim, and on a similar basis the time over the 801 miles of the northern line from Oslo to Bodö, when completed throughout, would be about 17 hr., and from Oslo to Mosjøen, 596 miles, approximately 12¾ hr.

NEW RAILCAR SERVICES IN ALGERIA

Single-unit 400 b.h.p. cars and 600 b.h.p. triple sets of welded steel construction

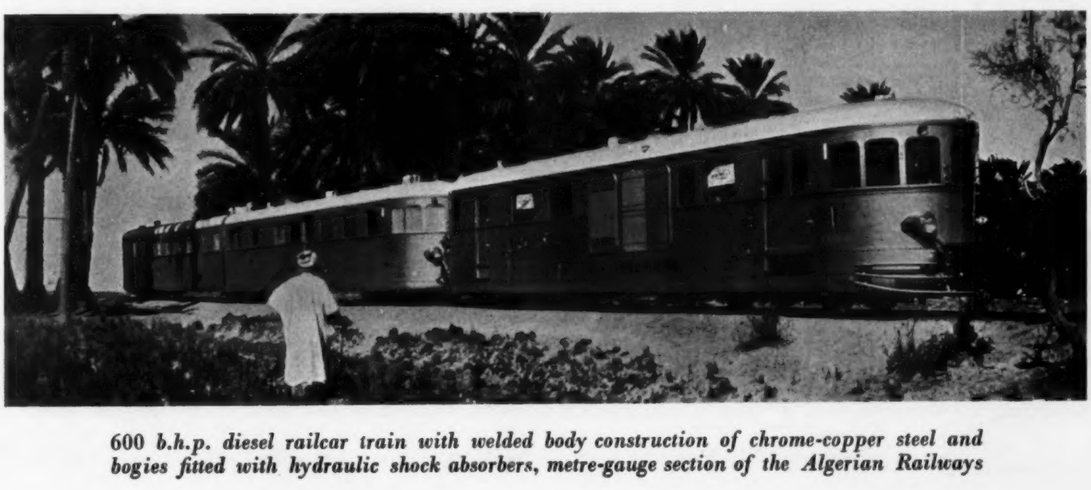
SOME five or six years ago the Algerian Railways began to use railcars for light passenger services with a handful of small Panhard-engined diesel cars, the capacity of which soon proved to be insufficient to meet the increasing demand. In 1937-38 five standard-gauge double-bogie 300 b.h.p. Renault diesel railcars were acquired and put into traffic on the main line, running to a schedule of five hours for the 262 miles separating Algiers from Oran.

Further railcar services began in February last between Constantine, on the Mediterranean coast, and Touggourt, in the centre of one of the date-palm areas, and which has both a large native population and an appreciable tourist traffic. The line is divided into two sections; first from Constantine to Biskra, 148 miles of standard-gauge track, and from Biskra to Touggourt 135 miles of metre-gauge track. Over the first division the new service is maintained by 96-seater Michelines, and over the inland narrow-gauge line by De Dietrich railcar trains. There is a 21 min. to 24 min. stop at Biskra for the change-over, but neglecting this the steam train time has been cut from 11 hr. 21 min. to 7 hr. 14 min. for the 283 miles from Constantine to Touggourt. Connections are made at El Guerrah, where the route crosses the main transversal railway of Algeria, to and from Algiers. Much of the gain in time (more than three hours) has been effected on the metre-gauge section, where, without any important modification or realignment of the permanent way, the railcars are allowed a top speed of 105 km.p.h. (65 m.p.h.) compared with the 60 km.p.h. (37 m.p.h.) of the steam trains. The greater rapidity of the daily railcar passenger service also assists the operation of the freight traffic at its peak, when, between the middle of October and the middle of December, much of the fruit from the 2½ million date-palms in the Touggourt area has to be transported over the line.

The Micheline pneumatic-tyred cars used between Constantine and Biskra are of Type 23, which is carried on three bogies—an eight-wheel carrying bogie at each end and an eight-wheel driving bogie in the centre. The driving thrust between the power bogie and the 100-ft. body is taken through two long thrust rods. Motive power is provided by a 12-cylinder vee 400 b.h.p. Panhard petrol engine, and the torque is transmitted *via* two Vulcan-Sinclair hydraulic couplings to two Cotal electromagnetic two-speed gearboxes, and thence through chains to the four axles of the driving bogies; a drive is taken from each end of the engine. Totals of 48 first-second and 48 third class seats are provided on a tare weight of 18 *tonnes,* and with a gross weight of about 26 *tonnes* the average wheel load is 1·1 *tonnes* and the b.h.p. over 15 per *tonne.* The top speed is 120 km.p.h. (75 m.p.h.), which can be attained quickly by reason of the large amount of power available.

Narrow-Gauge Railcars

For the Biskra—Touggourt service there are three De Dietrich railcar trains, each composed of a power car housing the engines and having baggage and light goods room and a twin-car articulated trailer. Two of the power cars house two Saurer BZD 12-cylinder vee engines with an individual output of 300 b.h.p. at 1,500 r.p.m. and in the third car are installed two Sulzer 6LDT19 engines set to give a maximum of 300 b.h.p. each at a speed of 1,175 r.p.m. Oerlikon electric transmission, with four traction motors per power car, is incorporated in all three sets, and the engine and main generator are carried as one group on a welded steel subframe supported on the main underframe. There is a driving position at each end of the power car. A complete three-car train tares about 69 *tonnes* and has a weight of approximately 80 *tonnes* when fully laden with 26 first or second class and 88 third class passengers. The power car weighs 36 *tonnes* empty and just over 39 *tonnes* gross. A buffet is fitted in one of the trailer cars. Compressed air braking, with two shoes per wheel, is incorporated, and can stop the train on the level in a distance of 220 yd. from a speed of 56 m.p.h. On the level the train can accelerate from rest to 30 m.p.h. in 45 sec., to 56 m.p.h. in 128 sec., and to the top speed of 65 m.p.h. in 215 sec. Heating of the train is effected by hot water from an oil-fired boiler in the power car. When required the power car can be used for the haulage of ordinary passenger stock or light freight trains.



600 b.h.p. diesel railcar train with welded body construction of chrome-copper steel and bogies fitted with hydraulic shock absorbers, metre-gauge section of the Algerian Railways

English-Built Railcar for Mountain-Grade Operation

STEADY progress is being made by the Peruvian Corporation in the application of diesel locomotives and railcars to a variety of services on the different lines which it owns, not only on the coastal lines but also on those at heights of 10,000 to 15,000 ft. above sea level. Not the least interesting of the technical problems is that associated with the maintenance of the engine power on vehicles working over such lines as the Peruvian Central, which climbs from sea level to 15,800 ft. in a distance of approximately 100 miles.

The latest unit for the Callao to Oroya line is a double-bogie double-engine car designed and built by Walker Bros. (Wigan) Ltd., in which the variation in altitude conditions has been met by the installation of a reciprocating blower for each power plant. These blowers, or pressure-chargers, were made at the Walker works, and were designed to give a uniform air delivery at a substantially constant pressure irrespective of the speed of revolution, and to absorb as small an amount of power as possible; they maintain the sea level output constant up to the highest summit. Tests have indicated that these blowers absorb appreciably less power than a rotary blower and give an air delivery at a lower temperature; in addition, the cost, all things considered, is no more than that of a proprietary make of pressure-charger.

In general design the car is similar to the Walker eight-wheel cars at work in Peru, Brazil and Ireland, but with the difference that each bogie carries a power-transmission equipment, instead of only one bogie as previously. The car body thus has an articulation pivot at each end. The individual power plants comprise a Gardner 6LW engine set to give 102 b.h.p. at 1,700 r.p.m., a Vulcan-Sinclair fluid coupling, a Wilson five-speed epicyclic gearbox, a Layrub cardan shaft, and a final spiral bevel and single helical drive on the reverse box, which is electro-pneumatically controlled. The car is arranged for dual-directional working, all the controls are synchronised and can be operated from either end of the car at will.

Each driving compartment is fitted with the requisite instruments and warning lights, giving full indication of the working of the transmission at the opposite end. Compressed-air throttle control of the maker's own design is incorporated, and is fitted with the dead-man feature, and enables the two engines to be synchronised easily. Its features allow the engine to be operated to give the best acceleration possible from the car and it is readily adaptable for multi-unit working.

The gilled-tube radiator is of the Spiral Tube type and is mounted on one side of the driving cabin. An inspection door at each end of the car above the couplings gives easy access to the auxiliary belt drives, brake compressor, blower, and radiator fan drive, and the engine and gearbox can be reached easily from the driving compartment. The radiators are of special design and fitted with bevel driven fans. Air is drawn from the lower part of the cab through a duct and expelled through the radiators. They are arranged for both water and oil cooling. The coach is fitted with heating pipes operated from the engine water circulation system, and is controlled from the driver's compartment.

In view of the severe grades—75 miles at 1 in 22-25 combined with numerous curves and 13 reversing stations —special attention has been paid to the braking equipment. In addition to the Westinghouse compressed air system applying two blocks on each wheel through clasp rigging, Metropolitan-Vickers electro-magnetic track brakes are incorporated, with two shoes per bogie. A handbrake in each cab operates the blocks on the adjacent bogie.

The bogies are built up on frames of steel plate and carry as integral structures the driving cabs, which are connected to the car body by simple vestibules. Timken roller bearings are used for all four axles, and are housed in inside axleboxes made at the Walker works; they are supported by overhung laminated springs with helical auxiliaries. The underframe is simply built up of riveted sections and has two main outer solebars; the underframe between the bogies is absolutely clear of equipment. Accommodation is provided for 40 first class passengers and one ton of luggage on a tare weight of 23·8 tons, and with a maximum axle load in the fully-laden condition of 8.25 tons. The gross weight of the car is about 27.5 tons.

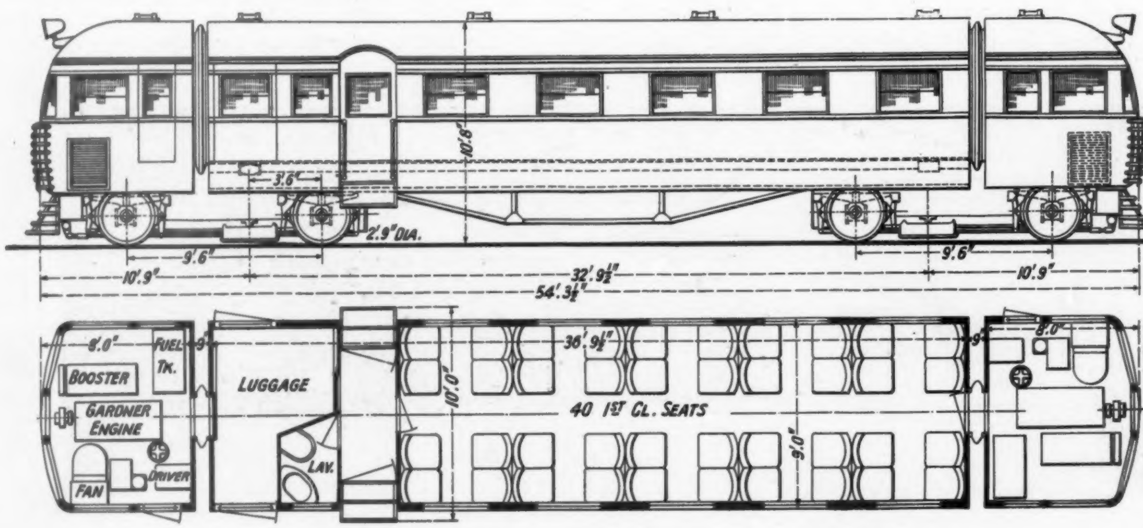
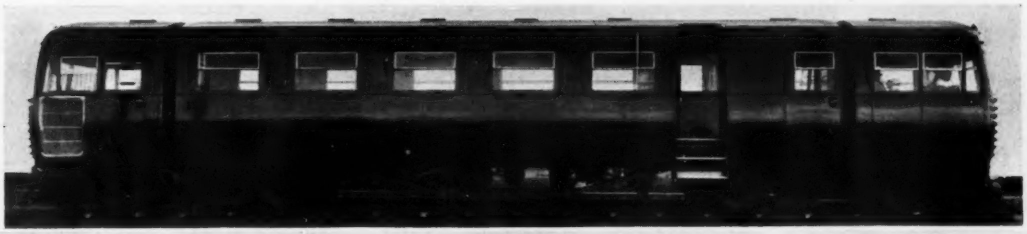
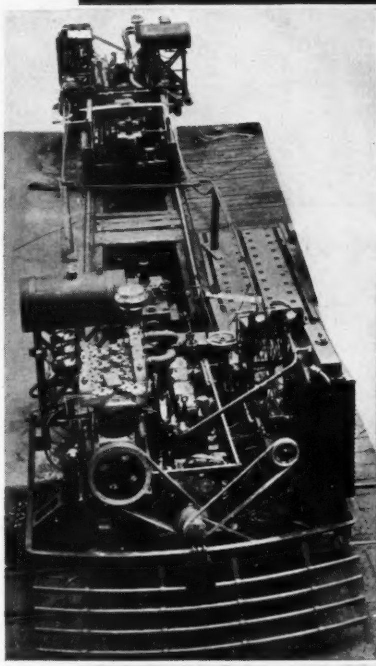
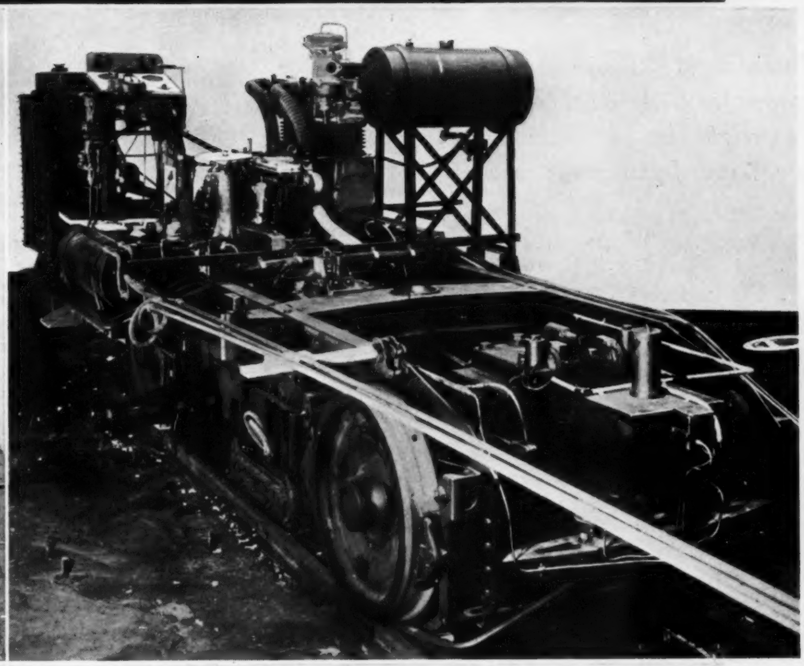
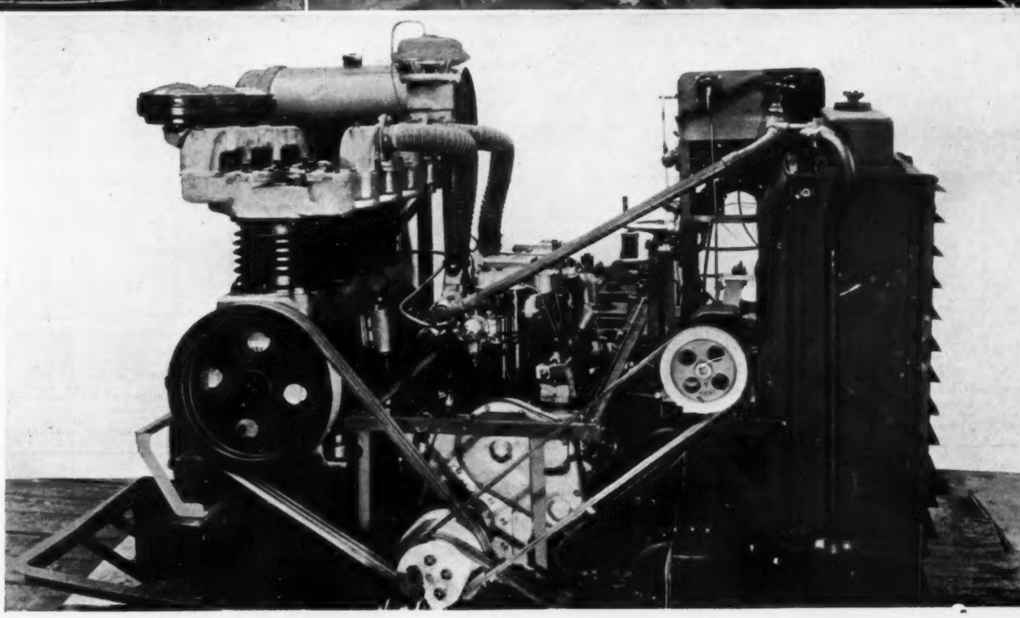


Diagram of double power-bogie car for the Peruvian Corporation







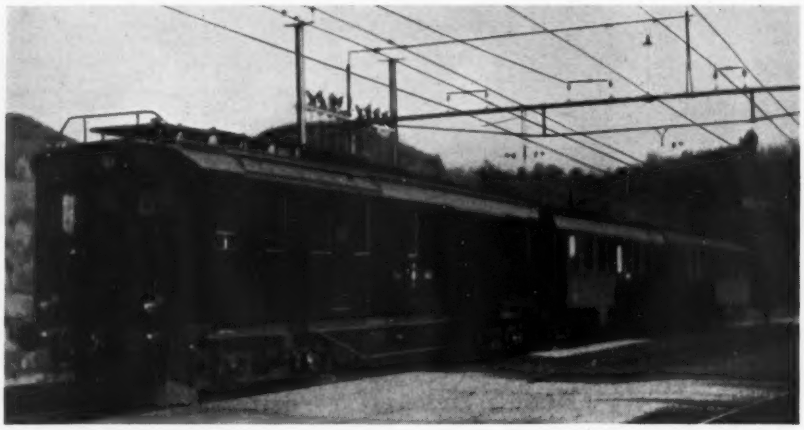


Top : The completed car, as photographed at the maker's Wigan works. Left centre : General view of the two bogies and their equipment. Right centre : General view of power bogie, showing electro-magnetic track brake shoes. Bottom : View of motive power equipment including the blower, main engine, and radiator

WALKER ARTICULATED RAILCAR FOR THE PERUVIAN CENTRAL RAILWAY

Rebuilt Diesel Railcar for Trailer Haulage in Switzerland

Increase of 33 per cent. in output for 6 per cent. increase in weight in car with luggage and light goods space



600-b.h.p. car hauling local passenger train at Neuhausen

AT the beginning of 1930 the Swiss Federal Railways put into traffic a double-bogie luggage van designed to haul passenger and freight trailers as required, and which was powered by a Sulzer six-cylinder four-stroke diesel engine giving 420 b.h.p. at 620 r.p.m. Oerlikon electric transmission, with two nose-suspended traction motors, was incorporated, and gave a one-hour tractive effort of 6,600 lb. at 17·8 m.p.h., a starting effort of 14,300 lb., and a top speed of 47 m.p.h. The car measured 57 ft. 9 in. over buffers, weighed 57 tons, and had an adhesion weight of 26·8 tons minimum.

Trailer weights up to 130 tons were dealt with over the non-electrified lines in northern Switzerland, but operating experience showed that the car would be a more valuable traffic unit if it had greater power. Therefore some time ago the car was rebuilt with a pressure-charger to give an output of 600 b.h.p., and the engine itself was modernised and the capacity of the electrical transmission equipment increased. Actually, the engine could give well over 700 b.h.p. if run at the normal Sulzer speed of 750 r.p.m., but as the requirements of the Swiss Federal Railways did not exceed an engine power of 600 b.h.p. the rotational speed has been fixed at 600 r.p.m. as a maximum.

Big Daily Mileage

The increase in output has been obtained without encroaching further upon the revenue-earning space of the car, the engine room as before being about 16 ft. 3 in. long. Nor has the weight been materially increased, the tare being 57·8 tons and the weight with supplies but without pay load about 60·3 tons. The top speed of the car has been increased to 56 m.p.h. and the tractive effort on the one-hour rating to 6,600 lb. at 25 m.p.h. The minimum adhesion weight is almost unaltered at 27 tons. The acceleration and speed uphill have been improved considerably, so that the car can haul its normal 60 to 70 tons of trailers, and well over 100 tons if re-

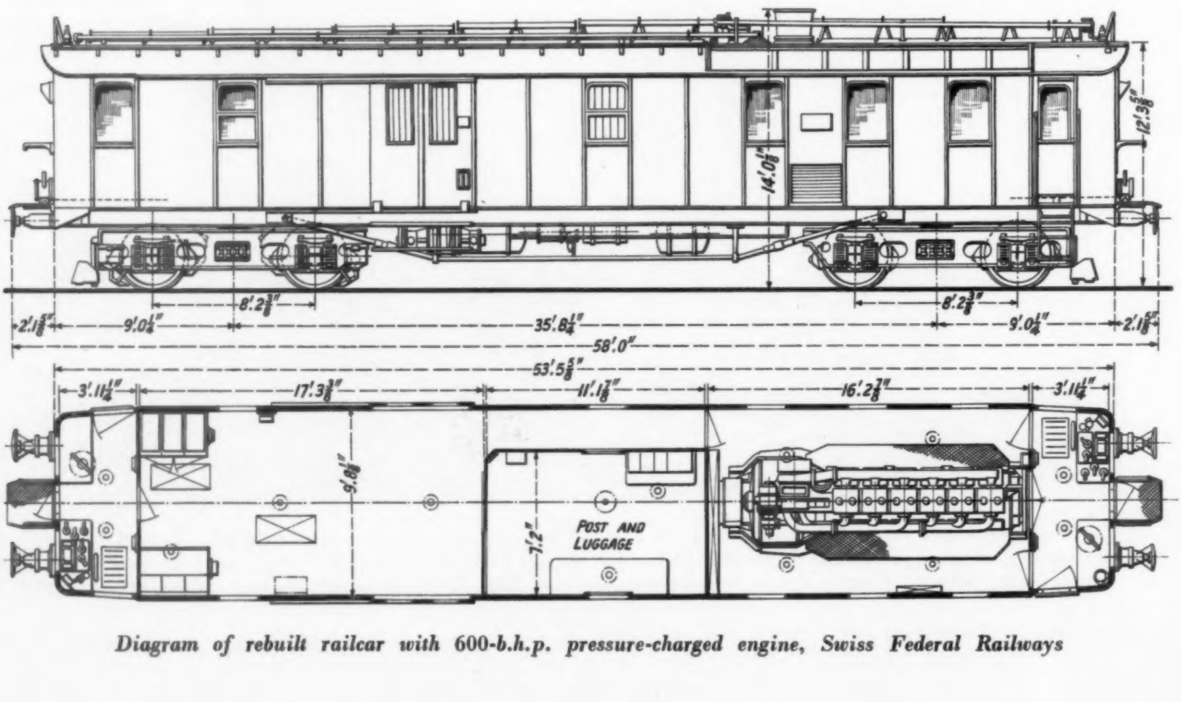
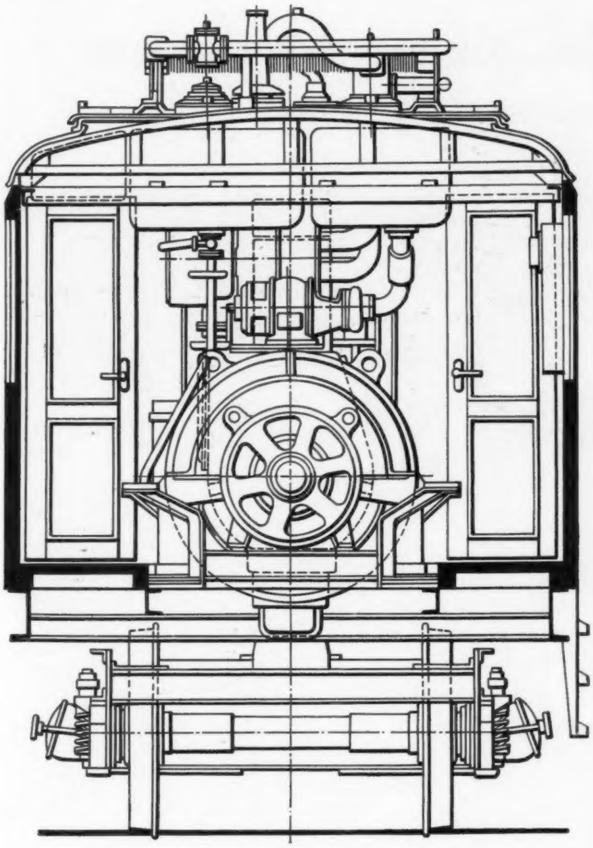


Diagram of rebuilt railcar with 600-b.h.p. pressure-charged engine, Swiss Federal Railways



Cross-section through engine room of the rebuilt and pressure-charged 600-b.h.p. Sulzer luggage railcar, Swiss Federal Railways

quired, to quicker schedules. At the moment the car is operating in passenger service over the Basle—Constance and Schaffhausen—Winterthur lines of the Federal Railways, with a maximum gradient of 1 in 83, and is making a daily mileage of 372, made up as follows:—

Winterthur	dep.	6·50	km.
Schaffhausen	arr.	7·31	30
,,	dep.	8·00	
Constance	arr.	9·20	48
,,	dep.	9·25	
Basle	arr.	12·39	151
,,	dep.	13·00	
Schaffhausen	arr.	15·15	103
,,	dep.	15·20	
Winterthur	arr.	16·00	30
,,	dep.	16·15	
Schaffhausen	arr.	16·56	30
,,	dep.	17·28	
Basle	arr.	19·24	103
,,	dep.	19·35	
Winterthur	arr.	21·33	105
			600

A Büchi exhaust-gas turbo pressure-charger has been fitted to give the majority of the **33** per cent. increase in engine power. It operates up to a maximum exhaust temperature of 550° C., which is rarely, if ever, reached in service, and runs at a top speed of approximately **20,000** r.p.m. At an engine speed of **610** r.p.m. the maximum charging pressure is **3·82** lb. per sq. in.

A 20-notch control is embodied, and it allows the engine to run either at **500/520** r.p.m. or **600/610** r.p.m. At these speeds the main generator has designed capacities of **300** and **380** kW respectively, but the ratings actually given to suit the particular application are as given in the table below.

	Main generator Continuous rating	One-hour rating
Volts	950/790	535
Amp.	286/340	490
kW	272/268	262
R.p.m.	650/520	650/520

The overhung auxiliary generator has corresponding ratings of:—

	Auxiliary generator Continuous rating	One-hour rating
Volts	150	150
Amp.	100	120
kW	15	18
R.p.m.	650/520	650/520

In the course of a run on this car recently between Winterthur and Schaffhausen, with a trailing load of about **60** tons, or a train weight of approximately **120** tons, we noted that the top engine speed of **610** r.p.m. was used only once, when accelerating up a **1** in **166** grade from a p.w. slack to walking pace; the main generator current under these conditions rose to a maximum of **300** amp. In general the train was hauled along the level and up slight grades at **40** to **44** m.p.h. with the engine running at **520** r.p.m., the controller handle on the last notch, and with a main generator output of about **180** kW, rising to **220** kW when accelerating on the same controller notch.

Steam and Diesel Traction

IN a lecture at Yale University on steam and diesel motive power units for rail traction, Mr. L. K. Sillcox emphasised that for shunting work the diesels could replace more efficiently at least twice the capacity of steam locomotives. For all speeds up to 6 m.p.h. a heavy **1,200** b.h.p. diesel locomotive could deliver higher torque and accelerate the maximum tonnage more quickly than a steam locomotive of **2,100** h.p. The superiority in this respect to a **1,300** h.p. steam locomotive extended up to 11 m.p.h. Comparison of service performance of diesel and steam switchers belonging to an eastern railroad are given in the accompanying table.

Speaking of main-line trains Mr. Sillcox said that a steam locomotive which demonstrated **65** per cent. availability was exceptional. This figure might be contrasted with the **95·4** per cent. of all the Burlington Zephyrs from the time the first set went into operation in 1934, up to July, 1938; or with the **98·4** per cent. of the G.M. & N.R.R. Rebel trains over one year, or the **84·6** per cent. of the Illinois Central's Green Diamond over the same period. Such intensive use went far towards justifying high initial cost.

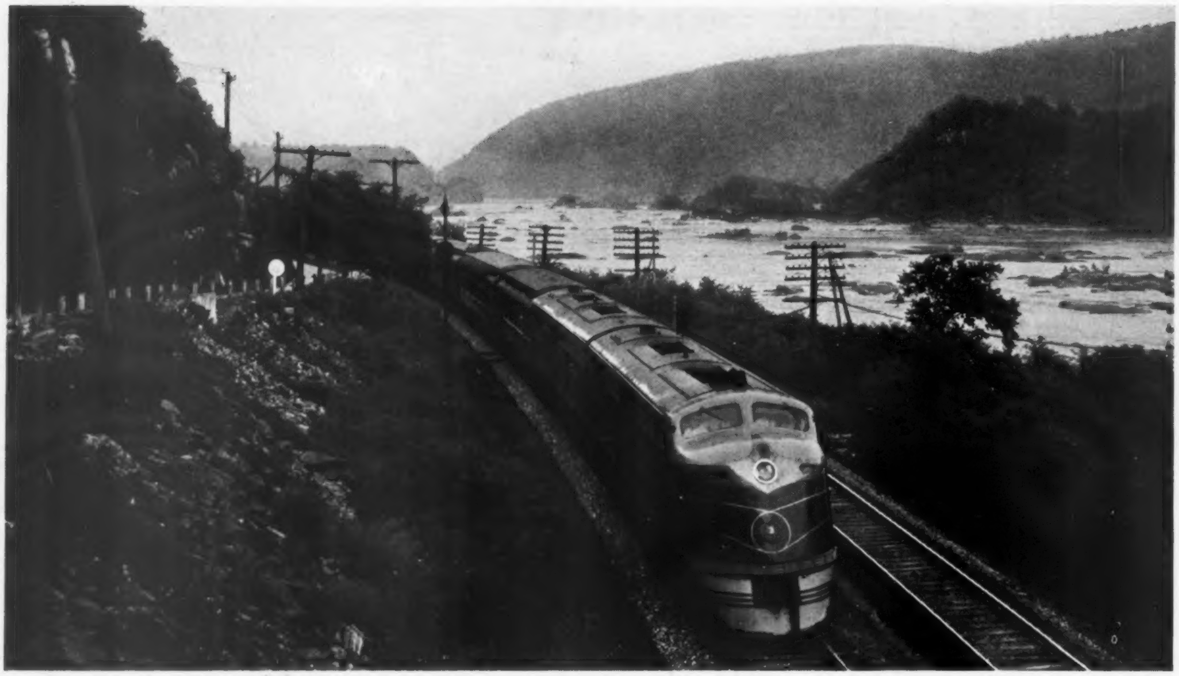
Comparative Shunting Locomotive Costs, Steam and Diesel (U.S.A.)

	Steam	Diesel
Service hours a year	4,650	6,500
Corresponding availability, per cent.	53·0	74·2
Costs of operation, per hour:	$	$
Fuel	0·820	0·296
Water	0·036	—
Lubrication	0·020	0·044
Repairs	0·725	0·535
Enginehouse expense	0·505	0·016
Other supplies	0·024	0·024
Wages (2 men in each case)	1·490	1·490
Depreciation at 4 per cent.	0·353	0·436
Interest at 5 per cent.	0·441	0·790
Insurance and taxes at 2 per cent.	0·177	0·316
Total hourly cost	4·591	3·947

Financial charges based on first costs of $41,000 for steam locomotive and $70,000 for diesel locomotive

MAIN-LINE DIESEL OPERATION ON THE BALTIMORE & OHIO

Locomotive haulage for heavy trains of standard stock



The Capitol Limited, hauled by one of the 3,600-b.h.p diesel-electric locomotives, in the Potomac valley en route from New York to Chicago

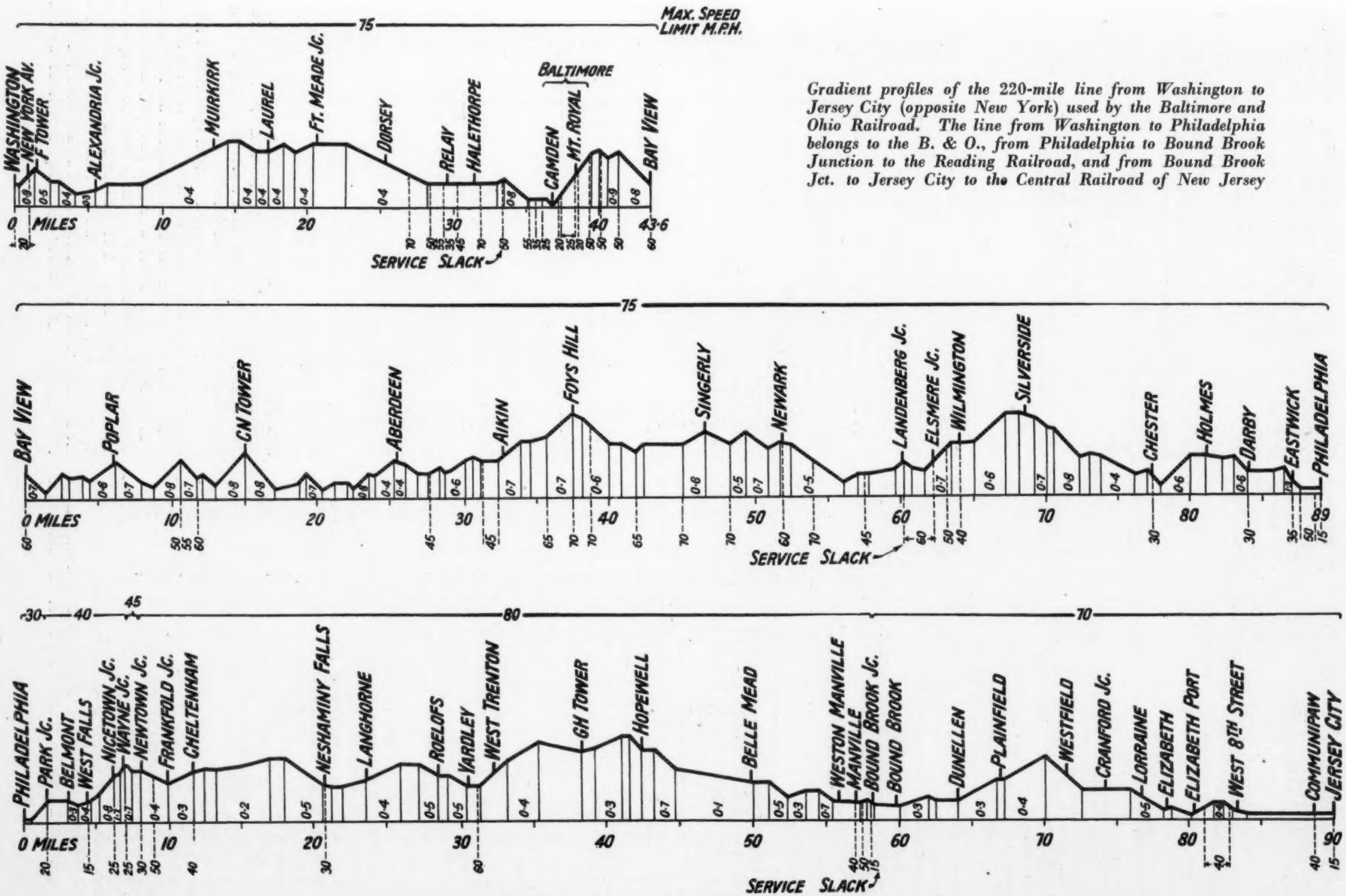
ONE of the earliest diesel locomotive users in the United States was the Baltimore & Ohio Railroad, which acquired about a dozen years ago one of the standard 300 b.h.p. Ingersoll-Rand double-bogie oil-electric shunting locomotives. About four years ago a much larger double-bogie Electro-Motive diesel locomotive of 1,800 b.h.p. was bought, and introduced first on the Royal Blue and then transferred to the Abraham Lincoln, one of the principal passenger trains on the Alton Railroad, a subsidiary of the B. & O. Subsequently twin-unit locomotives of 3,600 b.h.p.—each half with two six-wheel bogies—were acquired to haul the Royal Blue, Columbian, Capitol Limited and National Limited, the main express passenger trains of the B. & O. At the moment this line has six 3,600 b.h.p. and two 1,800 b.h.p. Electro-Motive diesel locomotives in main-line passenger service.

That success has attended the operation of these locomotives was evidenced a few months ago by Mr. C. W. Galloway, Vice-President of Operation and Maintenance, when he said: " The first 1,800 b.h.p. diesel-electric locomotive has hundreds of thousands of miles to its credit. It first hauled our Royal Blue Limited between New York and Washington, and is now daily speeding the Alton's Abraham Lincoln from Chicago to St. Louis and return. More evidence of our confidence and faith came when we placed orders for two of the 3,600 b.h.p. units, then another two, and still two more. May I give my testimony for the diesels by saying that it would be impossible for us to haul the Capitol Limited on its present fast schedule with any steam locomotive on the B. & O., but we can and do maintain the schedule with the diesel-electric—and at an even, sustained speed, usually on time—and with more time up our sleeve if our competitors begin to shorten their schedules. The first 3,600 b.h.p. unit that was delivered to us hauled a regular train of 14 heavy passenger cars, mostly Pullmans, from Chicago to Washington. We made a station stop on a one per cent. grade going up the west side of the Alleghenies, but we restarted easily and without shock to the train. We have no high-speed steam passenger locomotive that would do that alone."

The 3,600 b.h.p. locomotives have the 2(AIA-AIA) wheel arrangement and weigh 285 short tons. They are capable of speeds up to 110 m.p.h. and can attain a three-figure speed when hauling the Royal Blue and Columbian, which weigh on the average 650 to 670 short tons. The Capitol Limited normally loads to about 750 short tons. The starting tractive effort of the 3,600 b.h.p. locomotives is 90,000 lb. Each half unit contains two 12-cylinder 900 b.h.p. Winton two-stroke engines coupled to 700 kW main generators. The two units may be separated for turning, but only the front unit can be used as a 1,800 b.h.p. locomotive, for it houses all the controls except one low-speed system on the second unit for use during separated shunting movements. Hydraulic shock absorbers are fitted to the bogies in order to improve the riding. Other details of these locomotives were described in the issues of this Supplement dated April 16 and July 9, 1937.

As regards the 1,800 b.h.p. locomotives, the Coverdale & Colpitts report contains some figures relating to the operation of the eight-car 360- (short) ton Abraham Lincoln over the 282 miles between Chicago and St. Louis. The train makes one round trip daily at a schedule

Gradient profiles of the 220-mile line from Washington to Jersey City (opposite New York) used by the Baltimore and Ohio Railroad. The line from Washington to Philadelphia belongs to the B. & O., from Philadelphia to Bound Brook Junction to the Reading Railroad, and from Bound Brook Jct. to Jersey City to the Central Railroad of New Jersey



GRADIENT PROFILES OF THE ROUTE USED BY THE ROYAL BLUE AND COLUMBIAN TRAINS

speed of about 56 m.p.h. The ruling grades are 0·78 per cent. northbound and 0·7 per cent. southbound, and about 90 per cent. of the route is straight track. Over a period of seven months during which detailed figures were taken, and beginning after the train had been in traffic two and a half years, the diesel-hauled Abraham Lincoln showed the following results:—

		Per Train-Mile $
Revenue		3·02
Expenses	$	
Crew Wages	0·286	
Fuel	0·082	
Lubricants, &c.	0·035	
Enginehouse expense	0·019	
Train supplies and expenses	0·161	
Steam locomotive maintenance*	0·027	
Diesel locomotive maintenance	0·181	
Train maintenance	0·147	
Loss on dining-buffet car working	0·100	
	1·038	
Net revenue		1·982
Train-miles	119,568	
Passenger-miles	15,118,496	

* When diesel locomotive was out of service

Although the B. & O. have a general speed limit of 75 m.p.h. this appears to have been waived as far as the diesel-operated services between Washington and New York are concerned. From the two logs given on this page it will be seen that speeds over the eighty mark are frequent. The first run, behind locomotive DE-2, was with the first section of the Royal Blue, operated as a passenger extra with no booked stops between Baltimore and Jersey City, and to run as far in advance of schedule as consistent with safety. The only delay *en route* between Baltimore and Philadelphia was a p.w. check to 50 m.p.h. at Kiamensi, at m.p. $102\frac{3}{4}$, but between passing Philadelphia and the arrival at Jersey City the train was delayed near Wayne Jct. and thence to Newtown Jct. by the Reading Railroad train No. 441, and by a p.w. slack to 25 m.p.h. at Elizabethport. Speed rose to 83 m.p.h. within $8\frac{1}{2}$ miles of the start from Washington and was 86-87 m.p.h. down the 0·4 per cent. grade near Dorsey. From the Baltimore restart also, the speed rose to over 80 m.p.h. within the first nine miles, and up the 0·7 per cent. grade from Aikin to Foys Hill the train was accelerated from 59 to 64 m.p.h. The maximum speed over the whole run was 91 m.p.h., attained on a short down grade near Hamilton and again on a long 0·1 per cent. down grade near Belle Mead.

A run in the opposite direction with a lighter train load of 585 short tons tare behind the same locomotive is shown in the second log. As far as Philadelphia the locomotive was in charge of a driver who had just qualified on the diesels, and the times could probably have been improved with more experience. The Elizabethport p.w. slack to 25 m.p.h. was in force, and a reduction to 40 m.p.h. for a bridge repair at Kiamensi. The start from Wilmington was slow, as a driver obtaining experience on the

BALTIMORE & OHIO RAILROAD—THE ROYAL BLUE
WASHINGTON TO JERSEY CITY
DIESEL LOCOMOTIVE NO. DE-2. LOAD: 8 STREAMLINED CARS, 670 SHORT TONS

Miles		Min.	Sec.	M.p.h.
0·0	Washington .. dep.	0	00	—
0·8	New York Avenue	2	45	20*
5·5	Alexandria Jct.	8	30	76
13·7	Muirkirk	14	30	77
20·8	Fort Meade Jct.	19	45	84
31·4	Halethorpe	29	15	54*
36·8	Camden	36	00	18*
38·3	Baltimore (Mount Royal) .. arr.	39	30	—
0·0	do. do. .. dep.	0	00	—
5·3	Bay View	8	00	64*
11·7	Poplar	13	00	76
20·2	CN Tower	19	30	71
31·0	Aberdeen	27	30	77
38·2	Aikin	33	45	59
42·7	Foys Hill	38	00	64
51·7	Singerly	45	30	73
57·2	Newark	50	00	66
65·6	Landenberg Jct.	57	00	57*
67·5	Elsmere Jct.	59	00	62
69·4	Wilmington	61	00	52*
74·0	Silverside	65	45	68
82·5	Chester	71	45	54*
86·5	Holmes	75	45	69
89·6	Darby	78	15	62
92·3	Eastwick	80	45	59
92·7	East Side	81	15	48
94·4	Philadelphia	83	45	21*
96·0	Park Jct.	87	00	32*
97·6	Belmont	89	30	41
98·8	West Falls	91	15	30*
99·3	Bellevue Jct.	92	00	29*
100·6	Nicetown Jct.	94	15	31*
101·3	Wayne Jct.	96	15	21*
102·5	Newtown Jct.	98	45	42‡
104·3	Frankford Jct.	100	45	68
106·0	Cheltenham	102	00	72
115·2	Neshaminy Falls	109	15	50*
118·0	Langhorne	112	00	65
122·8	Roelofs	116	15	83
124·8	Yardley	117	45	72
126·6	West Trenton	119	15	67*
132·7	GH Tower	124	15	84
136·7	Hopewell	127	15	87
144·2	Belle Mead	132	30	91
150·2	Weston-Manville	136	30	79
151·4	Manville	137	30	60*
152·5	Bound Brook Jct.	139	00	22*
154·1	Bound Brook	141	15	57
158·4	Dunellen	145	15	75
161·3	Plainfield	147	45	72
165·8	Westfield	151	30	73
168·6	Cranford Jct.	153	45	73
171·1	Lorraine	155	45	71
172·8	Elizabeth	157	15	50
174·7	Elizabethport	160	30	24†
177·7	West 8th Street	165	15	51
183·0	Communipaw	170	15	50
184·3	Jersey City .. arr.	173	00	—

* Regular service slack. † P.w. slack. ‡ Signal slack

BALTIMORE & OHIO RAILROAD
TRAIN NO. 25. JERSEY CITY-BALTIMORE
DIESEL LOCOMOTIVE D.E.-2. LOAD: 7 STREAMLINED CARS, 585 SHORT TONS

Miles		Min.	Sec.	Speed M.p.h.
0·0	Jersey City	0	00	—
1·3	Communipaw	3	00	46
6·6	West 8th Street	8	00	56
9·6	Elizabethport	12	15	20†
11·5	Elizabeth .. arr.	16	00	—
0·0	Elizabeth .. dep.	0	00	—
1·7	Lorraine	3	00	52
4·2	Cranford Jct.	5	30	71
7·0	Westfield	7	45	74
11·5	Plainfield .. arr.	12	15	—
0 0	Plainfield .. dep.	0	00	—
2·9	Dunellen	3	45	75
7·2	Bound Brook	7	15	75
8·8	Bound Brook Jct.	9	15	17*
9·9	Manville	11	15	49*
11·1	Weston-Manville	12	45	60
17·1	Belle Mead	17	45	81
24·6	Hopewell	23	15	80
28·6	GH Tower	26	15	85
34·7	West Trenton	30	30	80
36·5	Yardley	32	00	67*
38·5	Roelofs	33	45	72
43·3	Langhorne	37	30	85
46·1	Neshaminy Falls	40	00	37*
55·3	Cheltenham	48	45	50*
57·0	Frankford Jct.	50	30	65
58·8	Newtown Jct.	52	30	41*
60·0	Wayne Jct. .. arr.	54	30	—
0·0	Wayne Jct. .. dep.	0	00	—
0·7	Nicetown Jct.	1	45	35
2·0	Bellevue Jct.	4	00	15*
2·5	West Falls	5	00	17*
3·7	Belmont	7	00	38
5·3	Park Jct.	10	00	22*
6·9	Philadelphia .. arr.	13	15	—
0·0	Philadelphia .. dep.	0	00	—
1·7	East Side	3	15	43*
2·1	Eastwick	4	00	45*
4·8	Darby	7	00	53*
7·9	Holmes	10	15	70
11·9	Chester	13	30	46*
20·4	Silverside	21	30	72
25·0	Wilmington .. arr.	25	30	—
0·0	Wilmington .. dep.	0	00	—
1·9	Elsmere Jct.	3	15	57
3·8	Landenberg Jct.	5	15	63
12·2	Newark	13	15	65
17·7	Singerly	17	45	77
26·7	Foys Hill	25	15	71
31·2	Aikin	28	45	65
38·4	Aberdeen	35	45	80
49·2	CN Tower	43	45	79
57·7	Poplar	50	30	82
64·1	Bay View	55	15	68
69·4	Baltimore Mt. Royal Station .. arr.	63	45	—

* Service slacks. † P.w. slack

diesels before qualification took over the controls. On this run, too, the maximum speed attained was 91 m.p.h. —on the 0·4 per cent. grade down to West Trenton, but 80 to 87 m.p.h. was maintained up the 0·1 per cent. grade south of Belle Mead. The start from Jersey City was 4 min. late, but 2¼ min. were made up by Philadelphia; starting from that station 2½ min. late, punctuality was regained just after Aberdeen.

Gradient profiles of the Washington—Jersey City line are reproduced on page 97. Between Washington and Philadelphia the line belongs to the B. & O., but from Philadelphia to Bound Brook Jct. the tracks of the Reading Railroad are used, and thence to Jersey City those of the Central Railroad of New Jersey. It will be observed that although the gradients are not particularly severe, there are numerous service slacks, often at inconvenient points as regards subsequent acceleration. Over the water-troughs near Dunellen and Aberdeen, the steam locomotives are restricted to 45 m.p.h., but this does not apply to the diesels.

FIRE

Letter to the Editor

Budapest,
May 4, 1939

To the Editor of the Diesel Traction Supplement

SIR,—On page 47 of the issue of March 17, 1939, of the *Diesel Railway Traction Supplement,* an article bearing the title " Fire " has been published, in which reference is made to the fire which occurred on one of the double diesel railcars supplied by us to Uruguay.

It would be not only in our interest, but also in the interest of the whole propaganda for diesel traction, if in a forthcoming issue of your journal you published a further short article in which the particular circumstances of this case of fire are elucidated, but in which it should be particularly pointed out that the causes of fire occurring in diesel railcars should under no circumstances be sought in the special nature of diesel traction itself. On the contrary, it should be pointed out that diesel traction as such offers a particularly high degree of safety of service, and that it is exactly the case of fire which occurred on the diesel railcar supplied by us to Uruguay which furnishes a striking example for this statement.

As regards the causes of the fire, it has not been possible to ascertain them beyond all doubt. The fire started in the interior of the car and all the evidence points to the fact that it was caused by gross neglect, if not, indeed, by ill-will. The fire spread so rapidly that within a short time the whole car body burnt out. All more or less inflammable parts of the vehicle were destroyed without a trace, and the fire completely deformed the steel structure of the car body, the roof, &c., and in many places even caused the structural parts to melt.

Nevertheless, the fuel tanks containing about 500 litres of diesel oil, remained perfectly intact, and not the slightest quantity of the fuel in the tanks was missing after the fire.

The damage suffered by the mechanical equipment was likewise of such a kind that the stock of lubricating oil contained in the engine and in the transmission gears remained perfectly intact. Another circumstance of particular interest is that the electrical equipment mounted in the immediate vicinity of the engines, such as the starting motors, also suffered no damage, so that any possibility of the fire having been caused by an electric short-circuit in these parts must be excluded.

It would appear from the above data that it was just those parts and elements of the diesel car which formed characteristic features of diesel traction that remained perfectly intact, and would seem to show the high degree of safety against fire offered by diesel operation.

GANZ & CO. LTD.

* * *

To say that we are delighted to hear of the cause of the fire on the Uruguay State Railways train would perhaps be stretching a point; but we are at least pleased that it is nothing inherent in the use of diesel engines which was the cause. We must admit that we began by thinking pretty much as our correspondent does, that the diesel railway vehicle is particularly immune from fire, and there is not the slightest doubt in circumstances such as those connected with the Uruguay train that the oil is not inflammable. If a fire begins in the passenger portion of the train the use of diesel motive power adds not the slightest risk to the spreading of the fire. Again, in the case of a collision the oil does not catch fire in the way in which petrol does.

Importance of Cleanliness

On the other hand, over the past two years we have been driven more and more towards the conclusion that the oil-engined vehicle is by no means so free from fire as we had at one time supposed, although it can be made so. It is true that a tank of oil may not catch fire, but on the other hand we have yet to see a diesel car in which there was not a good deal of oil spread over different parts of the engine room. If petrol were to spread in the same way it would very quickly evaporate, but the oil does not, and it is just this leakage of oil which seems to have given rise to quite a number of fires. There seems to be evidence to show that at least some of the fires which have occurred in railcars in France have been due to this cause, and as we indicated in our issue of March 20, 1936, the fire on the Santa Fe main-line locomotive was due to a similar cause through oil in a vapourised state getting into the engine room, where it was given every facility to catch fire. This tendency to leakage of oil which does not evaporate is a regrettable feature of diesel vehicles in their present state, but it is no use blinking at the fact. It is far better to recognise it and take every possible precaution against leakage of oil, in particular, absolute cleanliness of the engine room, and by careful attention to detail it is possible to reduce the leakage very considerably, rather than by purely propaganda methods which claim that diesel vehicles are absolutely free from fires. The cleanliness should extend also to the power bogies and underframes. In France these portions of railcars are given frequent washings with a jet of hot water under pressure. Again, certain railcar fires appear to have been caused by short circuits in main or auxiliary cables. Cables as a whole are particularly prone to corrosion by fuel oil, and although it is not always possible to keep them entirely out of harm's way, there is room for improvement in the specifications of cable sheathing. Among the precautions which may be taken to prevent fire or to restrict it spreading are the elimination of wood from the engine room, particularly the roof, and the use of metal anti-fire cross panels between the engine room and the revenue portion of the railcar. But the most efficacious preventive measure is strict cleanliness of the engine room, bogies and train.—EDITOR.

NOTES AND NEWS

G.W.R. Railcar Warning Equipment.—Totals of 72 compressed air Desilux horns and 72 Desilux auxiliary electric horns have been ordered from C. V. Desiderio, of London, W.1, for installation in the railcars now being built to A.E.C. designs for the Great Western Railway.

Diesel Shunters for South America.—Two small Whitcomb diesel-mechanical locomotives have been shipped recently from the U.S.A. to mines in Dutch Guiana, and are to be supplemented shortly by some 18-ton Whitcomb diesel locomotives to haul the ore to the mills.

Shunting Locomotives for Palestine.—The Consolidated Refineries Limited have ordered a diesel locomotive from John Fowler & Co. (Leeds) Ltd., to be equipped with a 110-b.h.p. Fowler-Sanders engine running at 850 r.p.m., a Traction-type gearbox, and a Vulcan-Sinclair fluid coupling with an idling drag eliminator.

D.E.U.A. Summer Meeting.—The annual outing of the Diesel Engine Users' Association is to be held this year on June 15, when a visit will be made to King's Lynn to inspect the St. German's pumping station of the Middle Level Catchment Board. The members are travelling with the 8.30 a.m. train from London (Liverpool Street).

Bulgarian Railcar Interest.—The Bulgarian State Railways are contemplating a wider extension of diesel railcar services, and at the moment seem to favour small German four-wheeled cars for local services and the French type of double-bogie car for more important traffic. Hitherto only four-wheeled cars of about 150 b.h.p. have been used.

Transandine Railcar Service.—In connection with the reopening of the Argentine section of the Transandine Railway, taken over and reconstructed by the Argentine Government Railways, it is proposed to run a weekly railcar service in each direction between Mendoza and Cacheuta, presumably with one of the metre-gauge Ganz diesel cars of the State Railways.

Jugoslav Railcar Services Proposed.—As a result of the operating success of the three-car Ganz trains introduced over the Belgrade-Dubrovnik narrow-gauge line in July of last year, and the tests made with Italian cars between Belgrade and Zagreb, the Jugoslav State Railways are proposing to introduce fast railcar services between Belgrade, Zagreb, and Ljubljana, and between Belgrade, Novi Sad, and Subotica.

American News.—The Missouri Pacific Railroad has received authority to purchase diesel equipment on the general lines indicated on p. 37 of the March 17 issue of this Supplement, but changes have been made so that the orders actually placed are for two 2,000-b.h.p. Electro-Motive diesel locomotives and two six-car trains for the St. Louis-Omaha service ; one 1,000-b.h.p., two 900-b.h.p., and two 600-b.h.p. oil-electric locomotives from the Electro-Motive Corporation ; one 1,000-b.h.p. oil-electric locomotive from the Baldwin Locomotive Works ; and one similar locomotive from Alco. The aggregate price of this equipment is understood to be about $5,000,000. The Phelps Dodge Corporation has ordered four 1,000-b.h.p. Electro-Motive diesel locomotives. The order for 30 diesel electric shunters placed by the Atchison, Topeka & Santa Fe Railroad at the end of 1938, and recorded in the issues of this Supplement for January 20 and March 17, has been divided as follows : 13 locomotives from Electro-Motive, 12 from Alco, and 5 from Baldwin. In addition, a 4,000-b.h.p. main-line Electro-Motive diesel locomotive has been ordered.

Arpad Railcar Service.—Beginning with the summer timetables on May 15, the morning Arpad railcar service from Budapest (Ost) to Vienna (Sud) was extended to Vienna (West), which is reached at 10.27, in time to connect with the Ostend train leaving at 10.45.

More Italian Railcars.—Five Fiat bogie railcars with engines suitable for use with diesel oil or methane are being put into traffic on the lines of the Soc. Ferrovie Val d'Orba, in the neighbourhood of Novi and Ovada. The engines have a top output of 115 b.h.p. at 1,800 r.p.m., and operate in conjunction with a four-speed transmission giving a maximum track speed of 43 m.p.h. Remote control coupling is embodied, so that the cars can run in multiple-unit, or in multiple-unit with the Fiat cars on the Italian State Railways.

English Shunting Locomotives.—An order for six diesel-mechanical locomotives to be powered by 150-b.h.p Fowler-Sanders engines has been received by John Fowler & Co. (Leeds) Ltd. from the Office of Works, and an order for two from the War Office. The locomotives for the Office of Works are to have flame-proof equipment. The same builder is also constructing a 220-b.h.p. diesel locomotive for Government service, and this is to be fitted with a Traction-type gearbox and Vulcan-Sinclair fluid coupling of the Hydraulic Coupling & Engineering Co. Ltd. These orders follow one for four 150-b.h.p. diesel locomotives placed with Fowler by the Air Ministry a few weeks ago.

British-American Papers.—The joint meeting of the Institution of Mechanical Engineers and the American Society of Mechanical Engineers to be held at New York on September 4–8 next will include papers on light-weight high-speed trains by Mr. W. A. Stanier, Chief Mechanical Engineer, L.M.S.R., and Mr. C. T. Ripley, Chief Engineer, Technical Board, Wrought Steel Wheel Industry, of Chicago.

Publications Received

Audel's Diesel Engine Manual.—By A. B. Green and R. A. Zoeller. London : Sir Isaac Pitman & Sons Ltd., Parker Street, W.C.2. 6¾ in. by 5 in. 292 pp. Illustrated. Price 10s. net. The Catechism has always been much more popular as a model for technical books in America than it has in England, and the present work, of American origin, is the latest in line of succession from M. N. Forney's celebrated *Catechism of the Locomotive*, of Victorian times. It is essentially a book for the man in charge of a diesel engine, and not for the designer ; and it is scarcely suitable for what are generally called " students." By means of questions and answers the authors go through the working principles and operation of diesel engines generally, then cover the detailed construction or working of certain constituents, such as the fuel-injection valves, pumps and piston rings, and finally deal with ancillary fittings, *e.g.*, lubricating and cooling systems, governors, and starting equipment. Although there is a short chapter on high-speed engines, the book really is one on the heavy slow-speed two-stroke and four-stroke stationary and marine types, with brief incursions into apparatus or details of high-speed engines, such as the Bosch fuel pump. The illustrations and descriptive matter refer only to engines and details made in the U.S.A.

SUPPLEMENT TO THE
RAILWAY GAZETTE

Financial and Operating Results

OF THE BRITISH GROUP RAILWAYS IN 1938

FRIDAY, MARCH 24, 1939

FINANCIAL AND OPERATING RESULTS OF THE BRITISH GROUP RAILWAYS IN 1938

An analysis of the accounts and statistics as shown in the published reports for the past year

THE accompanying tables and notes are compiled from the published accounts and statistics of the railway companies as set out in their annual reports. It is possible that differences in organisation, or methods of working, or in the nature of the traffic dealt with, limit the extent to which comparison can be made between one railway company and another, and this point should be borne in mind in perusing the tables and the notes relating thereto. In arranging the tables, however, every endeavour has been made to set out the figures in such a way as to afford a fair comparison between the companies, but for the reason already given it may not always be possible to compare results between one company and another in the various units of measurement adopted.

The year 1938 was disastrous for the railway companies, although there was no great national catastrophe, such as occurred in 1926, to bring about so great a decline in revenue. When it is remembered that in the first ten weeks of the year an advance of **£1,000,000**, equal to 3·57 per cent. in railway receipts, was recorded, the decline of nearly **£8,000,000** in gross receipts for the year from the whole of the businesses carried on by the railways is extremely disappointing and shows how acute the decline became as the year advanced. The figures will be dealt with more in detail later on, but four main reasons have been adduced to account for the decrease in revenue, *viz.*: (*a*) Recession in trade; (*b*) the international situation; (*c*) further inroads by competitive transport undertakings; and (*d*) reductions in charges to meet the increased competition.

It will be remembered that the railway companies obtained powers to increase their charges by 5 per cent. as from October 1, 1937, in order to meet the rising cost in working due to the increase in the costs of materials, especially coal; the restoration of the remainder of the wages cuts as from August 16, 1937, and the granting of improved conditions of service in various directions. When the Railway Rates Tribunal held the annual review of standard and exceptional charges in May, it stated in its judgment that from the evidence it did not appear that the reduction in the volume of railway traffics was accelerated to any material extent if at all by the increase in charges, and concluded that the net revenues of the railway companies were greater than they would otherwise have been, but it seems clear that as the year advanced it was found that traffic was being abstracted from rail, and the L.N.E.R. review of the company's business refers to considerable loss of short distance passenger traffic, whilst the Chairman of the L.M.S.R. mentioned in his speech the diversion of certain classes of merchandise traffic to other forms of transport.

Indeed, the appeal of the railway companies to the Government last November for a "square deal" emphasises the fact. In the document which has been sent out to the shareholders it is pointed out that the application of the standard scales of charges which were sanctioned by Parliament and came into force on January 1, 1928, provided, in the ten-year period 1928 to 1937 inclusive, revenues in the neighbourhood of **£150,000,000** short of the standard which by the Railways Act of 1921 the companies were entitled to earn. This appeal has come very prominently before the public and has been much discussed in the press. The Minister of Transport referred it to the Transport Advisory Council for urgent consideration and report, and the council's findings will no doubt be received very shortly. It should be borne in mind that co-ordination of charges between road and rail has never actually been brought about. In 1928 a Royal Commission was appointed to report upon transport questions, and in its final report in 1931 it found it impossible to make a positive proposal on co-ordination, but recommended the setting up of a Transport Advisory Council for this purpose. This council was established in 1934, and in July, 1937, in its report to the Minister of Transport, expressed the view that all forms of transport should, where practicable, be rate-controlled and that a rate structure for road transport should be devised and enforced. Although the Government accepted the principles of the report, no legislation has been introduced to carry them out. Hence the action of the railway companies in demanding the same freedom in regard to their charges as their competitors on the roads possess.

Operating methods on the railways generally continue to show steady improvement, and accelerations of both passenger and goods trains are reported. Last summer the L.M.S.R. had 63 passenger trains running 6,317 miles a day at 60 m.p.h. and over. The introduction of higher power locomotives had brought about a marked diminution in double heading. One of the Coronation Scot train sets and locomotives has been despatched to the United States for exhibition at the New York World's Fair and a tour of the American continent. Two historic centenaries were celebrated at Euston during 1938, namely, the opening of the London & Birmingham Railway and the introduction of the railway travelling post office. Extensive research work is going on at the new laboratory at Derby and important results are being achieved.

On the L.N.E.R. a notable record was set up by the streamlined locomotive *Mallard*, which during a test attained a speed of 125 m.p.h. Two new train sets with special buffet cars have been provided for use on the Flying Scotsman run, and a new train has also been provided for the Hook of Holland service. New freight rolling stock has been constructed for the conveyance of edible oils. Both the L.M.S.R. and L.N.E.R. are experimenting with the Hudd system of automatic train control. The latter company is putting in an installation between Edinburgh and Glasgow, on which section a collision between two passenger trains took place during a snowstorm in December, 1937. The L.N.E.R. has recently suffered two great losses in personnel, first by the retirement of the Chairman of the company, Mr. Whitelaw, at the end of September, and just recently by the retirement under the age limit of Sir Ralph Wedgwood, who has occupied the position of Chief General Manager since the amalgamation on January 1, 1923.

The G.W.R. reports the establishment of 71 new factories upon its system during the year. It has also made improvements to its rolling stock, including the provision of five buffet cars of a new design and the construction of additional diesel cars.

The Southern Railway celebrated at the beginning of October the centenary of Southampton Docks, which have developed so wonderfully in recent years. A new steamer has been put on the Lymington—Yarmouth (Isle of Wight) service, and the construction of a new cross-Channel vessel to replace the *Maid of Orleans* is under order. New rolling

stock is to be provided for the Waterloo & City Railway. The Southern Sales League inaugurated last year was taken up enthusiastically by the staff, and has proved a great success.

Turning to the actual accounts, the following facts emerge:—

Tables 1 and 2—Capital Expenditure

The net aggregate capital expenditure of the four companies has been £8,828,631, or not much more than half the forecast made at the beginning of the year. No doubt the setback in trade has accounted for the postponement of some of the works which it was contemplated would be carried out during 1938. On the L.M.S.R. £881,000 was spent on way and works, £1,637,000 on rolling stock, £72,000 on road vehicles, £45,000 on docks, £54,000 on hotels, and £96,000 on subscriptions to omnibus and road haulage companies. On the other hand sales of land resulted in a credit to capital of £309,000. As mentioned a year ago, electric passenger train services were brought into operation in the Wirral Peninsula between Birkenhead, West Kirby, and New Brighton on March 14, 1938. The expenditure during the year on way and works was spread over the system generally and included the provision of both passenger and goods station accommodation

(*Text continued on page* 6)

Table 1—Aggregate Capital Expenditure to December 31, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937 £	1938 £	1937 £	1938 £	1937 £	1938 £	1937 £	1938 £
LINES OPEN FOR TRAFFIC—								
Capital expended	317,340,793	318,221,688	236,868,454	238,387,468	125,720,775	126,241,185	124,349,639	126,088,064
	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles
Miles of railway open for traffic (per Statistical Return IA)	6,870	6,845	6,353	6,337	3,774	3,774	2,133	2,126
	£	£	£	£	£	£	£	£
Average per mile	46,192	46,490	37,285	37,618	33,312	33,450	58,298	59,308
Lines not open for traffic	123,257	123,257	173,008	158,899	158,186	480,568	240,173	158,660
Lines leased and lines jointly leased other than "J" joint lines	—	—	—	—	10,331	15,919	26,591	26,591
Rolling-stock	62,445,256	64,082,478	48,175,076	49,895,023	21,554,077	21,443,350	18,794,104	19,156,525
Manufacturing and repairing works and plant	9,068,275	9,027,879	6,465,872	6,573,538	4,320,557	4,440,750	2,450,176	2,299,982
Total capital expended upon railway	388,977,581	391,455,302	291,682,410	295,014,928	151,763,926	152,621,772	145,860,683	147,729,822
Road vehicles	1,647,643	1,719,774	1,432,707	1,448,975	1,197,997	1,225,635	177,653	191,952
Horses	—	—	—	—	82,635	73,477	36,647	29,997
Garages, stables, &c.	1,666,326	1,659,962	589,366	598,857	256,410	264,561	168,474	169,823
Steamboats	2,828,372	2,852,584	2,896,864	2,900,023	414,965	405,712	2,806,821	2,814,922
Canals	5,999,590	5,983,050	1,302,761	1,301,920	738,263	737,936	40,000	40,000
Docks, harbours, and wharves	10,217,076	10,262,572	24,968,309	25,028,587	20,962,973	20,885,340	13,820,398	14,031,907
Hotels	5,090,609	5,144,901	2,765,451	2,760,999	431,686	518,445	1,347,184	1,348,458
Electric power stations, &c.	1,666,892	1,694,739	188,193	187,395	34,179	18,378	711,214	713,633
Land, property, &c., not forming part of the railway or stations	14,128,634	13,956,961	11,184,383	10,927,169	3,239,849	3,328,020	5,573,105	5,565,652
Lines leased (Abstract "J")	259,930	249,590	339,752	328,867	—	—	—	—
Lines jointly owned (Abstract "J")	6,644,744	6,623,031	10,340,482	10,299,291	319,428	318,959	334,729	334,448
Subscriptions to other companies	11,364,480	11,460,716	4,046,950	4,101,272	4,732,507	4,749,545	545,740	545,740
Special items—								
Northern Counties Railway, Ireland	5,937,094	5,966,054	—	—	—	—	—	—
County Donegal Railways Joint Committee	164,566	165,609	—	—	—	—	—	—
Stamp duty on capital	84,195	84,195	173,249	173,249	62,878	62,878	72,929	72,929
East London Railway Electrification	—	—	83,215	83,215	—	—	—	—
London Passenger Transport Board	—	—	584,970	584,970	—	—	—	—
Twenty-ton wagons	—	—	—	—	1,144,523	1,144,523	—	—
Parliamentary expenses	6,611	6,611	10,450	10,450	8,532	8,532	—	—
TOTAL CAPITAL EXPENDITURE	£456,684,343	£459,285,651	£352,589,512	£355,750,167	£185,390,751	£186,363,713	£171,495,577	£173,589,283

Table 2—Annual Capital Expenditure to December 31, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937 £	1938 £	1937 £	1938 £	1937 £	1938 £	1937 £	1938 £
Lines Open for Traffic—								
Land and compensation ...	84,395	35,673	Cr. 128,426	Cr. 68,588	Cr. 15,365	Cr. 8,173	Cr. 4,041	39,752
Construction of way and stations, engineering, &c.	428,231	795,716	595,639	1,218,600	309,509	527,401	1,161,922	1,469,609
Law charges and Parliamentary expenses	4,010	256	8,920	3,337	2,542	1,182	577	2,997
Transfers	Cr. 140,896	49,250	385,871	228,489	—	—	—	226,067
Total	375,740	880,895	862,004	1,519,014	296,686	520,410	1,158,458	1,738,425
Lines not Open for Traffic—								
Land and compensation	—	—	20,046	5	7,666	40,669	1,500	Cr. 38,192
Construction of way and stations, engineering, &c.	—	—	37,066	21,148	52,639	278,981	87,952	Cr. 41,058
Law charges and Parliamentary expenses	—	—	791	255	1,064	2,732	184	Cr. 2,263
Transfers	—	—	—	Cr. 35,517	—	322,382	—	—
Total	—	—	57,903	Cr. 14,109	61,369	5,588	89,636	Cr. 81,513
Lines leased and lines jointly leased (other than "J" joint lines)—Total	—	—	—	—	51	—	—	—
Rolling-Stock—								
Locomotives	408,852	94,445	8	2,433	—	—	—	—
Rail motor vehicles	1,084	129,103	189,771	28,307	7,264	681	727,464	158,116
Carriages....	170,198	474,441	888,303	1,631,118	109,338	Cr. 117,444	325,976	204,305
Wagons and vans	1,026,742	805,565	7,664	54,684	38,943	6,036	—	—
Service vehicles....	44,971	133,838	11,530	3,405	—	—	—	—
Transfers	—	Cr. 170	—	—	—	—	—	—
Total	1,651,847	1,637,222	1,097,276	1,719,947	155,545	Cr. 110,727	1,053,440	362,421
Manufacturing and Repairing Works and Plant—								
Land and buildings	—	—	38,404	Cr. 5,520	36,152	75,194	14,264	Cr. 190,489
Plant and machinery	—	—	73,448	113,186	11,953	44,999	—	40,295
Total	63,364	Cr. 40,396	111,852	107,666	48,105	120,193	14,264	Cr. 150,194
Total capital expended upon railway	2,090,951	2,477,721	2,129,035	3,332,518	561,756	857,846	2,315,798	1,869,139
Horses	—	—	—	—	Cr. 1,685	Cr. 9,158	—	Cr. 6,650
Road vehicles	200,867	72,131	116,284	16,268	48,428	27,638	10,045	14,299
Garages, stables, &c.	28,593	Cr. 6,364	Cr. 21,275	9,491	3,168	8,151	—	1,349
Steamboats	Cr. 36,121	24,212	Cr. 35,251	3,159	—	Cr. 9,253	19,500	8,101
Canals	Cr. 1,090	Cr. 16,540	Cr. 392	Cr. 841	Cr. 15,263	Cr. 327	Cr. 37,700	—
Docks, harbours, and wharves	80,666	45,496	Cr.1,040,730	60,278	Cr. 52,979	Cr. 77,633	81,433	211,509
Hotels	139,613	54,292	32,835	Cr. 4,452	76,598	86,759	Cr. 41,066	1,274
Electric power, stations, &c.	3,624	27,847	Cr. 2,395	Cr. 798	—	Cr. 15,801	22,322	2,419
Land, property, &c., not forming part of the railway or stations	Cr. 203,691	Cr. 171,673	Cr. 256,583	Cr. 257,214	46,252	88,171	Cr. 18,468	Cr. 7,453
Lines leased—Total	Cr. 1,535	Cr. 10,340	Cr. 4,519	Cr. 10,885	—	—	—	—
Lines jointly owned—Total	Cr. 107,295	Cr. 21,713	Cr. 112,839	Cr. 41,191	435	Cr. 469	Cr. 619	Cr. 281
Subscriptions to other companies	43,021	96,236	48,735	54,322	29,000	17,038	—	—
Northern Counties Railway	2,830	28,960	—	—	—	—	—	—
County Donegal Railways Joint Committee	Cr. 294	1,043	—	—	—	—	—	—
Twenty-ton wagons	—	—	—	—	—	—	—	—
Total Capital Expenditure ...	£2,240,139	£2,601,308	£852,905	£3,160,655	£695,710	£972,962	£2,351,245	£2,093,706

Table 3—Revenue Receipts and Expenditure of the whole undertaking, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
RAILWAY—								
Gross Receipts (per Account No. 10)	£67,234,080	£64,212,115	£49,086,681	£46,656,115	£28,110,846	£26,829,140	£22,113,580	£22,012,051
Per cent. on capital expended	17·28	16·40	16·83	15·81	18·52	17·58	15·16	14·90
Expenditure (per Account No. 10)	£53,597,673	£53,355,771	£39,540,466	£40,541,280	£21,792,828	£22,192,996	£17,243,732	£17,736,373
Per cent. of gross receipts	79·72	83·09	80·55	86·89	77·52	82·72	77·98	80·58
Net receipts (per Account No. 10)	£13,636,407	£10,856,344	£9,546,215	£6,114,835	£6,318,018	£4,636,144	£4,869,848	£4,275,678
Per cent. on capital expended	3·51	2·77	3·27	2·07	4·16	3·04	3·34	2·89
ROAD TRANSPORT—								
Gross receipts (per Account No. 11)	£408,890	£403,846	£201,744	£203,596	£73,226	£70,077	£23,703	£24,625
Expenditure (per Account No. 11)	£339,625	£335,820	£162,840	£163,768	£59,378	£56,318	£17,384	£15,726
Per cent. of gross receipts	83·06	83·16	80·73	80·44	81·09	80·34	73·35	63·86
Net receipts or expenditure (per Account No. 11)	£69,265	£68,026	£38,904	£39,828	£13,848	£13,759	£6,319	£8,899
STEAMBOATS—								
Gross receipts (per Account No. 12)	£1,508,577	£1,399,493	£874,507	£812,774	£339,282	£348,292	£1,465,232	£1,539,787
Per cent. on capital expended	53·34	49·06	30·19	28·03	81·76	85·85	52·20	54·70
Expenditure (per Account No. 12)	£1,204,290	£1,192,814	£825,480	£830,702	£319,331	£324,753	£1,127,690	£1,142,115
Per cent. of gross receipts	79·83	85·23	94·39	102·21	94·12	93·24	76·96	74·16
Net receipts or expenditure (per Account No. 12)	£304,287	£206,679	£49,027	loss £17,928	£19,951	£23,539	£337,542	£397,672
Per cent. on capital expended	10·76	7·25	1·69	—	4·81	5·80	12·03	14·13
CANALS—								
Gross receipts (per Account No. 13)	£115,992	£120,926	£36,626	£34,959	£13,688	£13,862	£2,376	£1,750
Per cent. on capital expended	1·93	2·02	2·81	2·69	1·85	1·88	5·94	4·37
Expenditure (per Account No. 13)	£149,763	£149,790	£49,148	£51,456	£33,032	£35,017	£1,405	£804
Per cent. of gross receipts	129	124	134	147	241	253	59	46
Net receipts or expenditure (per Account No. 13)	loss £33,771	loss £28,864	loss £12,522	loss £16,497	loss £19,344	loss £21,155	£971	£946
Per cent. on capital expended	—	—	—	—	—	—	2·43	2·36
DOCKS, HARBOURS AND WHARVES—								
Gross receipts (per Account No. 14)	£1,102,586	£985,448	£2,794,047	£2,465,369	£2,242,128	£1,991,970	£1,283,242	£1,218,896
Per cent. on capital expended	10·79	9·62	11·19	9·85	10·70	9·54	9·29	8·69
Expenditure (per Account No. 14)	£1,067,339	£1,010,536	£2,546,196	£2,382,449	£1,899,746	£1,789,842	£903,798	£882,107
Per cent. of gross receipts	96·80	102·55	91·13	96·63	84·73	89·85	70·43	72·37
Net receipts (per Account No. 14)	£35,247	loss £25,088	£247,851	£82,920	£342,382	£202,128	£379,444	£336,789
Per cent. on capital expended	0·34	—	0·99	0·33	1·63	0·97	2·75	2·40
HOTELS AND REFRESHMENT ROOMS AND CARS WHERE CATERING IS CARRIED ON BY THE COMPANY—								
Gross receipts (per Account No. 15)	£3,080,014	£3,080,430	£2,073,970	£2,060,966	£767,014	£773,246	£147,518	£135,617
Per cent. on capital expended	60·50	59·87	74·99	74·65	178	149	10·95	10·06
Expenditure (per Account No. 15)	£2,727,005	£2,749,519	£1,908,511	£1,928,383	£726,857	£726,506	£130,083	£123,217
Per cent. of gross receipts	88·54	89·26	92·02	93·57	94·76	93·96	88·19	90·87
Net receipts (per Account No. 15)	£353,009	£330,911	£165,459	£132,583	£40,157	£46,740	£17,435	£12,400
Per cent. on capital expended	6·93	6·43	5·98	4·80	9·30	9·02	1 29	0·92

(Continued on next page)

Table 3—Revenue Receipts and Expenditure of the whole undertaking, Years 1937 and 1938—*Continued*

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
COLLECTION AND DELIVERY OF PARCELS AND GOODS—								
Gross Receipts (per Account No. 16)	£2,377,276	£2,231,146	£1,362,669	£1,332,035	£1,038,194	£1,012,235	£542,975	£534,350
Expenditure (per Account No. 16)	£2,839,257	£2,802,407	£1,766,518	£1,641,784	£1,278,274	£1,259,237	£532,344	£520,736
Per cent. of gross receipts	119·43	125·61	129·63	123·26	123·12	124·40	98·04	97·45
Net receipts (per account No. 16)	loss £461,981	loss £571,261	loss £403,849	loss £309,749	loss £240,080	loss £247,002	£10,631	£13,614
AIR TRANSPORT—								
Gross receipts (per Account No. 19)	£28,121	£19,390	—	—	£2,169	£905	£2,210	£1,389
Expenditure (per Account No. 19)	£64,656	£52,902	—	—	£11,999	£4,814	£7,313	£6,364
Per cent. of gross receipts	230	273	—	—	553	532	331	458
Loss (per Account No. 17)	loss £36,535	loss £33,512	—	—	loss £9,830	loss £3,909	loss £5,103	loss £4,975
CAPITAL EXPENDED	£456,684,343	£459,285,651	£352,589,512	£355,750,167	£185,390,751	£186,363,713	£171,495,577	£173,589,283
TOTAL—								
Gross receipts (per Account No. 8)	£75,855,536	£72,452,794	£56,430,244	£53,565,814	£32,586,547	£31,039,727	£25,580,836	£25,468,465
Per cent. on capital expended	16·61	15·78	16·00	15·06	17·58	16·66	14·92	14·61
Expenditure (per Account No. 8)	£61,989,608	£61,649,559	£46,799,159	£47,539,822	£26,121,445	£26,389,483	£19,963,749	£20,427,442
Per cent. of gross receipts	81·72	85·09	82·93	88·75	80·16	85·18	78·04	80·21
Net receipts (per Account No. 8)	£13,865,928	£10,803,235	£9,631,085	£6,025,992	£6,465,102	£4,650,244	£5,617,087	£5,041,023
Per cent. on capital expended	3·04	2·35	2·73	1·69	3·49	2·50	3·28	2·90

Table 4—Receipts in Respect of Railway Working (per Account No. 10), Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
PASSENGER TRAIN TRAFFIC—								
Passengers, including season and workmen's tickets	£20,379,099	£20,544,528	£13,153,370	£12,812,305	£8,508,647	£8,469,196	£14,661,033	£14,698,605
Per cent. of traffic receipts	30·61	32·32	27·01	27·70	30·55	31·85	67·10	67·61
Mails, parcels under 2 cwt., parcels post excess luggage, and other merchandise, per passenger train	£6,615,212	£6,532,200	£4,471,661	£4,544,856	£2,980,496	£2,984,804	£2,258,580	£2,288,892
Per cent. of traffic receipts	9·94	10·28	9·18	9·83	10·70	11·23	10·34	10·53
Total passenger train receipts	£26,994,311	£27,076,728	£17,625,031	£17,357,161	£11,489,143	£11,454,000	£16,919,613	£16,987,497
Per cent. of traffic receipts	40·55	42·60	36·19	37·53	41·25	43·08	77·44	78·14
GOODS TRAIN TRAFFIC—								
Merchandise (excluding classes 1–6)	£18,824,622	£17,224,043	£12,618,037	£11,953,313	£7,617,167	£7,310,832	£2,632,051	£2,580,201
Per cent. of traffic receipts	28·28	27·10	25·91	25·85	27·35	27·50	12·04	11·87
Minerals and merchandise (Classes 1–6)	£6,515,877	£5,413,530	£4,908,440	£4,086,042	£2,564,743	£2,008,727	£608,986	£503,615
Per cent. of traffic receipts	9·79	8·52	10·08	8·83	9·21	7·55	2·79	2·32
Coal, coke and patent fuel	£13,649,766	£13,325,071	£13,173,969	£12,485,707	£5,918,685	£5,585,311	£1,631,875	£1,616,441
Per cent. of traffic receipts	20·50	20·96	27·05	27·00	21·25	21·01	7·47	7·43
Livestock	£582,890	£523,019	£371,955	£365,816	£261,912	£227,693	£57,897	£51,318
Per cent. of traffic receipts	0·88	0·82	0·77	0·79	0·94	0·86	0·26	0·24
Total goods train receipts	£39,573,155	£36,485,663	£31,072,401	£28,890,878	£16,362,507	£15,132,563	£4,930,809	£4,751,575
Per cent. of traffic receipts	59·45	57·40	63·81	62·47	58·75	56·92	22·56	21·86
TOTAL TRAFFIC RECEIPTS	£66,567,466	£63,562,391	£48,697,432	£46,248,039	£27,851,650	£26,586,563	£21,850,422	£21,739,072
Miscellaneous	£666,614	£649,724	£389,249	£408,076	£259,196	£242,577	£263,158	£272,979
TOTAL RECEIPTS IN RESPECT OF RAILWAY WORKING	£67,234,080	£64,212,115	£49,086,681	£46,656,115	£28,110,846	£26,829,140	£22,113,580	£22,012,051

(*Continued from page* 2)

and additional sidings at many points, whilst track circuits, telephones and telegraphs cost nearly £140,000. In rolling stock 19 additional railmotor vehicles, 166 coaching vehicles, 4,551 wagons, and 217 service vehicles were provided. The hotel capital expenditure was incurred mainly at Edinburgh and Leeds, whilst the largest outlay under the head of subscriptions was in respect of Joseph Nall & Co. Ltd.

On the L.N.E.R. £3,160,655 was spent as against a forecast of £8,385,000. Out of £1,505,000 spent on way and works, London suburban electrification was responsible for £845,000. Rolling stock cost £1,720,000, of which all but £200,000 was in respect of 503 new carriages and restaurant cars. Sums of £60,000 were spent on docks and £108,000 on workshops. Sales of land realised £76,000. The company reports good progress with the electrification in the London suburban area and with the construction of engine sheds at Darnall and Wath in connection with the Manchester—Sheffield—Wath electrification. A significant paragraph in the review of the company's business during 1938 points out that since 1923 up to the end of last year 2,452 economy schemes involving initial expenditure have been carried out.

Table 5—Number of and Receipts from Passengers and Average Receipt per Passenger, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
ORDINARY PASSENGERS—								
First class— Number	3,952,249	3,583,020	2,841,172	2,695,542	1,146,852	1,081,394	4,722,924	4,373,279
Receipts	£1,398,849	£1,449,790	£884,972	£863,975	£532,841	£533,009	£999,565	£929,425
Average per passenger	7/0·94	8/1·11	6/2·76	6/4·92	9/3·51	9/10·29	4/2·79	4/3·01
Second class— Number	9,451	—	1,008,557	153,055	—	—	581,302	539,109
Receipts	£119	—	£104,404	£81,314	—	—	£409,420	£373,801
Average per passenger	3·02d.	—	2/0·84	10/7·51	—	—	14/1·04	13/10·41
Third class— Number	235,036,297	214,545,317	161,688,243	145,517,501	87,190,788	79,906,295	165,869,427	157,583,055
Receipts	£15,480,096	£15,578,878	£9,723,860	£9,349,986	£7,038,709	£6,999,061	£8,916,393	£8,928,435
Average per passenger	1/3·81	1/5·43	1/2·43	1/3·42	1/7·37	1/9·02	1/0·90	1/1·60
WORKMEN'S TICKETS—								
Number	91,463,506	90,534,526	48,279,232	47,683,952	27,967,349	28,087,206	74,676,028	73,960,298
Receipts	£1,229,348	£1,255,384	£721,931	£730,472	£329,598	£338,738	£1,128,742	£1,139,372
Average per passenger	3·23d.	3·33d.	3·59d.	3·68d.	2·83d.	2·89d.	3·63d.	3·70d.
TOTAL— Number	330,461,503	308,662,863	213,817,204	196,050,050	116,304,989	109,074,895	245,849,681	236,455,741
Receipts	£18,108,412	£18,284,052	£11,435,167	£11,025,747	£7,901,148	£7,870,808	£11,454,120	£11,371,033
Average per passenger	1/1·15	1/2·22	1/0·84	1/1·50	1/4·30	1/5·32	11·18	11·54d.
SEASON TICKETS—								
First class— Number	18,263	17,449	14,246	14,100	3,426	3,227	21,689	21,322
Receipts	£490,641	£480,588	£303,376	£311,384	£92,957	£88,870	£577,308	£574,887
Second class— Number	373	—	32,720	1	—	—	—	—
Receipts	£1,899	—	£391,863	£24	—	—	—	—
Third class— Number	196,506	191,821	108,852	143,285	65,665	62,989	199,752	202,205
Receipts	£1,778,147	£1,779,888	£1,022,964	£1,475,150	£514,542	£509,518	£2,629,605	£2,752,685
TOTAL— Number	215,142	209,270	155,818	157,386	69,091	66,216	221,441	223,527
Receipts	£2,270,687	£2,260,476	£1,718,203	£1,786,558	£607,499	£598,388	£3,206,913	£3,327,572
TOTAL RECEIPTS FROM PASSENGERS, INCLUDING SEASON TICKETS	£20,379,099	£20,544,528	£13,153,370	£12,812,305	£8,508,647	£8,469,196	£14,661,033	£14,698,605

The cost was £5,860,000, but the annual savings and net revenue arising therefrom have been £1,703,000, equal to 29 per cent. on the outlay.

The G.W.R. spent £973,000 on capital, of which £848,000 was on way and works. This latter figure included £320,000 on new lines from North Acton to Northolt Junction and from Northolt Junction to Ruislip, and the electrification of these lines is proceeding satisfactorily. Station improvements have been carried out at Plymouth, Paignton, Penzance, Weymouth, and Leamington Spa. Capital expenditure on workshops was £120,000, but there is a credit of £126,000 under rolling stock in respect of Great Western and London Passenger Transport Board joint vehicles.

The Southern Company's actual capital expenditure of £2,093,000 approached most nearly to its forecast; £1,054,000 was spent on electrification, £182,000 on the new line Motspur Park to Leatherhead, £362,000 on electric rolling stock, £211,000 on Southampton Docks, and £30,000 on the new steamer for the Lymington and Isle of Wight service. As regards electrification, the new line from Motspur Park to Tolworth was opened in May, and on July 3 the full electric service between London and Portsmouth *via* Chichester and between Brighton and Portsmouth and on the Bognor Regis and Littlehampton branches, came into operation. The electrification from Virginia Water to Reading, Ascot to Ash Vale, Frimley to Pirbright Junction, and Aldershot North Junction to Guildford was completed for opening at the beginning of 1939, and work is proceeding apace on the electrification of some of the Kentish lines. Many station improvements are also reported. At the annual meeting of the company the Chairman stated that there had been an increase of £180,000 in passenger receipts in the electrified areas and that in every case the capital spent on electrification had earned a net income far in excess of the interest required for the loans.

As regards capital expenditure, in 1939 the L.M.S.R. proposes to spend £2,329,000, including £1,229,000 on way and works, £558,000 on rolling stock, £174,000 on workshops,

(*Text continued on page* 11)

Table 6—Tonnage, Receipts, and Average Receipt per ton from Merchandise (excluding Classes 1-6), Minerals and Merchandise (Classes 1-6), and Coal, Coke, and Patent Fuel, and Total Goods Train Receipts, Years 1937 and 1938

	L.M.S.R.		L.N.E.R		G.W.R		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
MERCHANDISE (excluding classes 1–6)—								
Tonnage	29,570,757	25,973,566	22,324,952	19,790,161	13,534,323	12,445,503	5,026,839	4,692,839
Receipts	£18,824,622	£17,224,043	£12,618,037	£11,953,313	£7,617,167	£7,310,832	£2,632,051	£2,580,201
Average per ton	12/8·78d.	13/3·15d.	11/3·65d.	12/0·96d.	11/3·07d.	11/8·98d.	10/5·66d.	10/11·96d.
Percentage of total goods train receipts	47·57	47·21	40·61	41·37	46·55	48·31	53·38	54·30
MINERALS AND MERCHANDISE (classes 1–6)—								
Tonnage	30,753,305	25,222,484	26,861,977	22,329,327	12,161,076	9,336,745	2,958,948	2,346,720
Receipts	£6,515,877	£5,413,530	£4,908,440	£4,086,042	£2,564,743	£2,008,727	£608,986	£503,615
Average per ton	4/2·85d.	4/3·51d.	3/7·85d.	3/7·92d.	4/2·62d.	4/3·63d.	4/1·39d.	4/3·50d.
Percentage of total goods train receipts	16·47	14·84	15·79	14·14	15·68	13·27	12·35	10·60
COAL, COKE, AND PATENT FUEL—								
Tonnage	78,773,979	72,893,543	86,644,194	78,665,979	46,367,787	42,487,630	8,434,979	8,193,857
Receipts	£13,649,766	£13,325,071	£13,173,969	£12,485,707	£5,918,685	£5,585,311	£1,631,875	£1,616,441
Average per ton	3/5·59d.	3/7·87d.	3/0·49d.	3/2·09d.	2/6·64d.	2/7·55d.	3/10·43d.	3/11·35d.
Percentage of total goods train receipts	34·49	36·52	42·40	43·22	36·17	36·91	33·10	34·02
TOTAL—								
Tonnage	139,098,041	124,089,593	135,831,123	120,785,467	72,063,186	64,269,878	16,420,766	15,233,416
Receipts	£38,990,265	£35,962,644	£30,700,446	£28,525,062	£16,100,595	£14,904,870	£4,872,912	£4,700,257
Average per ton	5/7·27d.	5/9·55d.	4/6·24d.	4/8·68d.	4/5·62d.	4/7·66d.	5/11·22d.	6/2·05d.
LIVE STOCK—								
Number	5,907,111	5,481,905	3,880,816	3,559,078	2,149,083	1,895,186	555,615	471,843
Receipts	£582,890	£523,019	£371,955	£365,816	£261,912	£227,693	£57,897	£51,318
Percentage of total goods train receipts	1·47	1·43	1·20	1·27	1·60	1·51	1·17	1·08
TOTAL GOODS TRAIN RECEIPTS	£39,573,155	£36,485,663	£31,072,401	£28,890,878	£16,362,507	£15,132,563	£4,930,809	£4,751,575

Table 7—Originating Freight Traffic, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
Merchandise (excluding Classes 1-6)	19,004,580	16,574,085	16,709,960	14,662,516	9,354,363	8,302,888	3,119,680	2,854,682
Minerals and merchandise (Classes 1-6)	24,722,839	20,404,604	22,079,490	17,928,387	8,782,542	6,333,310	1,428,012	1,252,766
Coal, coke, and patent fuel	63,933,220	59,439,896	75,962,906	68,901,956	38,178,999	34,719,812	3,340,517	3,121,653
Total	107,660,639	96,418,585	114,752,356	101,492,859	56,315,904	49,356,010	7,888,209	7,229,101
Principal Traffics—								
Bricks, blocks, and tiles	2,252,767	1,540,149	2,039,357	1,662,268	439,617	332,531	110,558	82,834
Cement and lime	1,334,382	1,189,507	875,797	743,896	540,198	548,797	246,519	202,520
Creosote, tar, and pitch	878,417	793,226	730,058	669,902	213,498	193,614	125,371	123,288
Grain, flour, and milling offals	615,382	552,764	1,262,102	1,220,529	956,360	880,344	198,833	144,412
Gravel and sand	1,054,861	926,186	662,503	568,468	299,720	199,618	93,389	97,335
Iron and steel blooms, billets, ingots, &c.	1,548,507	1,194,073	1,876,208	1,372,560	1,281,087	822,154	3,617	2,428
Iron and steel scrap	2,467,560	2,176,741	1,852,364	1,505,859	1,039,754	736,408	178,585	123,339
Iron and steel, other descriptions	3,733,074	2,981,615	3,625,785	3,024,124	1,720,331	1,247,665	41,863	35,703
Iron ore	4,780,660	3,916,457	6,120,016	4,771,078	1,457,218	876,481	5,627	3,230
Iron, pig	1,925,179	1,193,965	1,145,281	685,313	570,470	329,017	1,588	627
Limestone and chalk	2,897,110	2,380,828	1,843,923	1,498,970	418,472	290,126	58,383	63,708
Manure, packed	245,348	263,347	700,823	656,380	143,207	144,479	105,296	90,493
Oil cake	474,396	489,578	272,629	224,096	240,344	214,409	51,104	46,150
Road making and road repairing material	1,616,985	1,574,048	480,117	422,081	810,563	721,757	189,735	143,549
Round timber, including mining	369,644	299,114	1,407,597	986,497	993,146	848,368	36,037	32,410
Timber, other than round	906,349	676,248	830,193	621,430	259,272	208,135	108,424	78,973
Vegetables	265,391	230,845	1,301,102	991,847	92,879	89,789	51,584	51,834
Livestock—	Heads	Heads	Heads	Heads	Heads	Heads	Heads	Heads
Horses	8,436	7,910	6,987	4,342	12,674	11,168	3,325	1,785
Cattle	1,048,343	913,030	871,081	747,148	377,219	311,460	100,280	82,493
Calves	109,714	90,571	95,159	87,287	83,625	64,435	9,499	8,220
Sheep and lambs	2,501,717	2,481,509	1,446,800	1,395,774	642,797	592,364	230,362	195,200
Pigs	479,292	393,861	583,022	519,371	363,879	289,574	128,654	108,282
Miscellaneous	251	438	189	169	52	49	57	12
Total	4,147,753	3,887,319	3,003,238	2,754,091	1,480,246	1,269,050	472,177	395,992

Table 8—Expenditure in respect of Railway Working, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
A.—Maintenance of Way and Works.	£7,570,416	£7,569,682	£5,371,239	£6,139,557	£3,256,487	£3,344,153	£3,528,870	£3,590,302
Per cent. of traffic expenditure	14·14	14·19	13·54	15·10	15·01	15·12	20·49	20·26
B.—Maintenance of Rolling-Stock.	£8,882,333	£8,806,474	£8,443,596	£8,549,840	£3,434,833	£3,625,768	£2,526,358	£2,571,935
Per cent. of capital expenditure on rolling-stock.	14·22	13·74	17·53	17·14	15·94	16·91	13·44	13·43
Per cent. of traffic expenditure	16·59	16·51	21·28	21·02	15·83	16·40	14·67	14·51
C.—Locomotive Running Expenses.	£13,433,796	£13,495,623	£10,016,984	£10,130,500	£5,341,381	£5,459,425	£4,364,925	£4,582,248
Per cent. of traffic expenditure.	25·09	25·30	25·25	24·91	24·62	24·69	25·34	25·86
D.—Traffic Expenses	£19,283,378	£19,284,396	£13,186,998	£13,320,848	£7,622,955	£7,707,453	£5,267,937	£5,432,997
Per cent. of traffic expenditure.	36·01	36·14	33·24	32·76	35·14	34·86	30·59	30·66
E.—General Charges	£2,375,356	£2,174,853	£1,294,053	£1,298,290	£1,022,122	£972,793	£756,503	£754,091
Per cent. of traffic expenditure.	4·43	4·08	3·26	3·19	4·71	4·40	4·39	4·26
Law Charges	£65,542	£64,544	£40,928	£37,814	£38,184	£22,465	£26,550	£23,392
Per cent. of traffic expenditure.	0·12	0·12	0·10	0·09	0·18	0·10	0·15	0·13
Parliamentary Expenses	£12,376	£10,546	£1,728	£2,644	£1,238	£623	£2,000	£2,000
Per cent. of traffic expenditure.	0·02	0·02	—	0·01	—	—	0·01	0·01
Compensation	£403,731	£427,849	£319,579	£246,469	£149,926	£140,771	£88,253	£91,229
Per cent. of traffic expenditure.	0·75	0·78	0·81	0·61	0·69	0·64	0·51	0·51
Rates Tribunal	£4,228	£4,395	£3,505	£3,268	£2,262	£2,040	£1,959	£1,776
Per cent. of traffic expenditure	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01
Rates, Taxes and Tithe Rent Charges	£249,512	£261,708	£190,800	£175,792	£192,523	£204,345	£124,830	£126,958
Per cent. of traffic expenditure	0·47	0·49	0·48	0·43	0·89	0·92	0·73	0·72
Railway Freight Rebates Fund	£746,120	£745,202	£519,145	£492,829	£546,400	£544,038	£371,082	£379,432
Per cent. of traffic expenditure	1·39	1·40	1·31	1·21	2·52	2·46	2·16	2·14
National Insurance Acts	£532,851	£515,567	£426,109	£421,876	£243,517	£241,288	£161,477	£165,170
Per cent. of traffic expenditure	1·00	0·97	1·07	1·04	1·12	1·09	0·94	0·93
G.—Running Powers (Balance)	Cr. £10,137	Cr. £5,510	Cr. £140,076	Cr. £156,245	Cr. £156,277	Cr. £152,861	£2,492	£512
Per cent. of traffic expenditure	0·02	0·01	0·35	0·38	0·72	0·69	0·01	—
Total Traffic Expenditure	£53,549,502	£53,355,329	£39,674,588	£40,663,482	£21,695,551	£22,112,301	£17,223,236	£17,722,042
Per cent. on traffic receipts	80·44	83·93	81·47	87·92	77·90	83·17	78·82	81·52
Per train-mile	6s. 7·71d.	6s. 8·40d.	6s. 10·05d.	7s. 1·36d.	6s. 4·22d.	6s. 6·62d.	4s. 11·09d.	4s. 11·09d.
H.—Mileage Demurrage and Wagon Hire (Balance)	£1,819	Cr. £40,576	Cr. £167,473	Cr. £155,089	£94,441	£77,514	£15,697	£9,076
Miscellaneous	£46,352	£41,018	£33,351	£32,887	£2,836	£3,181	£4,799	£5,255
Total expenditure	£53,597,673	£53,355,771	£39,540,466	£40,541,280	£21,792,828	£22,192,996	£17,243,732	£17,736,373
Per cent. on receipts in respect of railway working	79·72	83·09	80·55	86·89	77·52	82·72	77·98	80·58
Per train-mile	6s. 7·79d.	6s. 8·40d.	6s. 9·77d.	7s. 1·10d.	6s. 4·56d.	6s. 6·90d.	4s. 11·16d.	4s. 11·14d.

Table 9—Maintenance and Renewal of Way and Works, Abstract "A," Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
Miles of line maintained reduced to single track (including sidings) (per Statistical Return X)	19,081	19,039	16,303	16,297	8,688	8,684	5,295	5,300
Train mileage (per Statistical Return XIIB)	161,224,565	159,263,296	116,049,802	114,333,866	68,314,864	67,504,497	69,958,739	71,981,195
Traffic receipts (per Account No. 10)	£66,567,466	£63,562,391	£48,697,432	£46,248,039	£27,851,650	£26,586,563	£21,850,422	£21,739,072
Superintendence (Salaries and Office Expenses)	£504,289	£509,291	£306,721	£309,625	£189,781	£193,287	£179,206	£186,312
Per mile of single track	£26·43	£26·75	£18·81	£19·00	£21·85	£22·26	£33·85	£35·15
Per train-mile	0·75d.	0·77d.	0·64d.	0·65d.	0·67d.	0·69d.	0·62d.	0·62d.
Maintenance of Roads, Bridges and Works	£875,140	£866,904	£615,224	£735,723	£398,966	£367,965	£430,225	£475,519
Per mile of single track	£45·87	£45·53	£37·74	£45·14	£45·92	£42·37	£81·25	£89·72
Per train-mile	1·30d.	1·31d.	1·27d.	1·54d.	1·40d.	1·31d.	1·48d.	1·59d.
Maintenance of Permanent Way—								
Complete Renewals—								
Mileage of single track renewed (per Statistical Return X)	635	659	293	347	261	248	209	186
Wages	£363,824	£391,769	£182,513	£220,190	£158,608	£153,649	£151,208	£156,129
Per mile of single track	£19·07	£20·58	£11·20	£13·51	£18·25	£17·69	£28·56	£29·46
Per mile of single track renewed	£573	£594	£623	£635	£608	£620	£723	£839
Per train-mile	0·54d.	0·59d.	0·38d.	0·46d.	0·56d.	0·55d.	0·52d.	0·52d.
Materials	£917,007	£1,233,060	£475,798	£703,779	£427,248	£460,562	£453,949	£464,024
Per mile of single track	£48·06	£64·77	£29·18	£43·19	£49·18	£53·04	£85·73	£87·55
Per mile of single track renewed	£1,444	£1,871	£1,624	£2,028	£1,637	£1,857	£2,172	£2,495
Per train-mile	1·37d.	1·86d.	0·99d.	1·48d.	1·50d.	1·64d.	1·56d.	1·55d.
Engine power and wagon repairs	£76,594	£70,342	£35,607	£37,547	£25,799	£22,904	£29,413	£25,750
Per mile of single track	£4·01	£3·69	£2·18	£2·30	£2·97	£2·64	£5·55	£4·86
Per mile of single track renewed	£121	£107	£121	£108	£99	£92	£141	£138
Per train-mile	0·11d.	0·10d.	0·07d.	0·08d.	0·09d.	0·08d.	0·10d.	0·08d.
Total	£1,357,425	£1,695,171	£693,918	£961,516	£611,655	£637,115	£634,570	£645,903
Per mile of single track	£71·14	£89·04	£42·56	£59·00	£70·40	£73·37	£119·84	£121·87
Per mile of single track renewed	£2,138	£2,572	£2,368	£2,771	£2,344	£2,569	£3,036	£3,472
Per train-mile	2·02d.	2·55d.	1·44d.	2·02d.	2·15d.	2·27d.	2·18d.	2·15d.
Percentage of capital expenditure on way and works (per Account No. 4)	0·43	0·53	0·29	0·40	0·48	0·50	0·51	0·51
Repairs and Partial Renewals—								
Wages	£2,130,422	£2,161,440	£1,713,608	£1,829,862	£974,274	£1,018,438	£827,956	£877,823
Per mile of single track	£111·65	£113·53	£105·11	£112·28	£112·14	£117·28	£156·36	£165·63
Per train-mile	3·17d.	3·26d.	3·54d.	3·84d.	3·42d.	3·62d.	2·84d.	2·93d.
Materials	£519,288	£643,022	£527,154	£752,940	£151,639	£138,776	£342,591	£343,770
Per mile of single track	£27·21	£33·77	£32·33	£46·20	£17·46	£15·98	£64·70	£64·86
Per train-mile	0·77d.	0·97d.	1·09d.	1·58d.	0·53d.	0·49d.	1·17d.	1·15d.
Engine power and wagon repairs	£103,177	£87,189	£66,763	£63,200	£56,937	£61,054	£25,231	£16,322
Per mile of single track	£5·41	£4·58	£4·10	£3·88	£6·55	£7·03	£4·77	£3·08
Per train-mile	0·16d.	0·13d.	0·14d.	0·13d.	0·20d.	0·22d.	0·09d.	0·05d.

(*Continued on next page*)

Table 9—Maintenance and Renewal of Way and Works, Abstract " A," Years 1937 and 1938—*Continued*

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
REPAIRS AND PARTIAL RENEWALS—*continued* *Total*	£2,752,887	£2,891,651	£2,307,525	£2,646,002	£1,182,850	£1,218,268	£1,195,778	£1,237,915
Per mile of single track	£144·27	£151·88	£141·54	£162·36	£136·15	£140·29	£225·83	£233·57
Per train-mile	4·10d.	4·36d.	4·77d.	5·55d.	4·15d.	4·33d.	4·10d.	4·13d.
MAINTENANCE OF SIGNALLING	£708,285	£713,435	£610,464	£665,245	£287,303	£290,626	£411,070	£455,482
Per mile of single track	£37·12	£37·47	£37·45	£40·82	£33·07	£33·47	£77·63	£85·94
Per train-mile	1·05d.	1·08d.	1·26d.	1·40d.	1·01d.	1·03d.	1·41d.	1·52d.
MAINTENANCE OF TELEGRAPHS AND TELEPHONES	£206,236	£196,276	£159,707	£179,322	£88,567	£83,308	£88,595	£100,431
Per mile of single track	£10·81	£10·31	£9·80	£11·00	£10·19	£9·59	£16·73	£18·95
Per train-mile	0·31d.	0·30d.	0·33d.	0·38d.	0·31d.	0·29d.	0·30d.	0·33d.
MAINTENANCE OF ELECTRIC TRACK EQUIPMENT	£32,037	£34,932	£11,949	£10,704	£3,207	£1,566	£79,718	£86,982
Per mile of single track	£1·68	£1·83	£0·73	£0·66	£0·37	£0·18	£15·06	£16·41
Per train-mile	0·05d.	0·05d.	0·02d.	0·02d.	0·01d.	0·01d.	0·27d.	0·29d.
MAINTENANCE OF STATIONS AND BUILDINGS	£1,133,961	£1,231,984	£782,545	£876,240	£455,143	£520,423	£753,003	£850,917
Per mile of single track	£59·43	£64·71	£48·00	£53·77	£52·39	£59·93	£142·21	£160·55
Per train-mile	1·69d.	1·85d.	1·62d.	1·84d.	1·60d.	1·85d.	2·58d.	2·84d.
TRANSFER TO OR FROM SUSPENSE ACCOUNT	£156	Cr. £569,962	Cr. £116,814	Cr. £244,820	£39,015	£31,595	Cr. £243,295	Cr. £449,159
Total of abstract	£7,570,416	£7,569,682	£5,371,239	£6,139,557	£3,256,487	£3,344,153	£3,528,870	£3,590,302
Per mile of single track	£396·75	£397·59	£329·46	£376·73	£374·83	£385·10	£666·45	£677·41
Per train-mile	11·27d.	11·41d.	11·11d.	12·89d.	11·44d.	11·89d.	12·11d.	11·97d.
Per cent. on traffic receipts	11·37	11·91	11·03	13·28	11·69	12·58	16·10	16·52
QUANTITIES OF PRINCIPAL MATERIALS USED (PER STATISTICAL RETURN X)—								
Ballast	Yards 577,750	Yards 509,720	Yards 509,119	Yards 537,053	Yards 303,335	Yards 298,830	Yards 355,822	Yards 339,976
Rails	Tons 96,831	Tons 99,358	Tons 48,674	Tons 55,148	Tons 30,978	Tons 30,659	Tons 31,874	Tons 29,328
Sleepers	No. 1,663,374	No. 1,667,714	No. 1,245,140	No. 1,388,934	No. 662,689	No. 633,641	No. 683,525	No. 628,004

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£184,000 on steamboats, £40,000 on docks, £31,000 on road vehicles and garages, £29,000 on hotels, and £65,000 on subscriptions to other undertakings. The L.N.E.R. proposes to spend £5,279,000, mainly on way and works, which will cost £4,109,000. Rolling stock will cost £669,000, workshops £150,000, docks £124,000, and the electrification of the line between Harrow and Rickmansworth £182,000.

The G.W.R. estimate is £1,482,000, made up of £769,000 on way and works, £561,000 on new lines, £94,000 on hotels, and £58,000 on workshops.

The Southern is proposing to spend £1,450,000, made up of £500,000 on electrification, £400,000 on electric trains, £200,000 on station improvements, £100,000 on the new line from Motspur Park to Leatherhead, and £250,000 on Southampton Docks.

Table 3—Revenue Receipts and Expenditure of the Whole Undertaking

A year ago an increase in receipts of £8,759,485 was noted for the year 1937 in comparison with 1936. This year the receipts have fallen by £7,926,363 in comparison with 1937, and it may be of interest to compare the figures of each company over the past three years. They are as follow:—

	1936	1937	1938
	£	£	£
L.M.S.R.	72,718,669	75,855,536	72,452,794
L.N.E.R.	53,943,907	56,430,244	53,565,814
G.W.R.	30,763,033	32,586,547	31,039,727
S.R.	24,268,069	25,580,836	25,468,465
	181,693,678	190,453,163	182,526,800

It will be seen that although in 1938 the aggregate receipts exceeded those of 1936 by £833,000, the figures of the two northern companies were less in 1938 than in 1936, whilst the G.W.R. had an increase of £276,000 and the Southern an increase of £1,200,000. The fact that the Southern is mainly a passenger line no doubt partly accounts for its more favourable position in comparison with the other companies, but its bold policy of electrification appears to

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Table 10—Maintenance of Rolling-Stock, Abstract "B," Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
ENGINE MILES PER STATISTICAL RETURN XIIc—								
Steam	227,876,435	220,737,198	172,707,839	167,775,664	99,511,068	97,474,115	49,470,019	46,695,989
Electric Traction	6,211,764	6,784,219	1,460,832	1,792,619	369,131	—	33,212,992	37,467,973
Steam Rail Motors	74,854	65,338	3,124,036	2,244,917	—	—	18,654	2,430
Any other form of power	797,675	746,413	98,743	122,011	910,815	1,015,673	19,125	82,635
Total	234,960,728	228,333,168	176,391,450	171,935,211	100,791,114	98,489,788	82,720,790	84,249,027
TRAFFIC RECEIPTS PER ACCOUNT No. 10—								
Passenger	£26,994,311	£27,076,728	£17,625,031	£17,357,161	£11,489,143	£11,454,000	£16,919,613	£16,987,497
Goods	£39,573,155	£36,485,663	£31,072,401	£28,890,878	£16,362,507	£15,132,563	£4,930,809	£4,751,575
Total	£66,567,466	£63,562,391	£48,697,432	£46,248,039	£27,851,650	£26,586,563	£21,850,422	£21,739,072
STOCK OF ENGINES, &c., PER STATISTICAL RETURN IIA— Locomotives—								
Steam	7,657	7,613	6,576	6,518	3,632	3,630	1,814	1,816
Electric	—	—	13	13	—	—	—	—
Internal-Combustion	31	31	2	2	1	1	3	3
Rail Motor Vehicles—								
Steam	5	5	80	80	—	—	1	1
Electric	249	268	108	109	20	—	1,394	1,511
Internal-Combustion	3	6	4	4	18	18	—	—
Total	7,945	7,923	6,783	6,726	3,671	3,649	3,212	3,331
LOCOMOTIVES, &c., COMPLETELY RENEWED PER STATISTICAL RETURN XI— Locomotives—								
Steam	266	92	147	91	150	122	—	11
Internal-Combustion	—	—	—	—	—	—	3	—
Rail Motor Vehicles— Steam	—	—	—	—	—	—	—	—
Electric	—	—	—	—	—	—	59	81
Internal-Combustion	—	—	—	—	—	—	—	—
SUPERINTENDENCE (SALARIES, OFFICE EXPENSES)	£347,817	£360,826	£299,794	£301,864	£115,633	£117,411	£101,135	£97,790
LOCOMOTIVES AND TENDERS (STEAM)—								
Complete renewals	£1,018,108	£492,804	£519,636	£464,109	£473,215	£490,588	£41,084	£31,694
Repairs and Partial Renewals	£3,324,603	£3,421,732	£3,133,565	£3,222,595	£1,455,970	£1,519,374	£709,408	£767,746
Per engine	£434	£449	£476	£494	£401	£419	£391	£423
Per engine-mile (steam)	3·50d.	3·72d.	4·35d.	4·61d.	3·51d.	3·74d.	3·44d.	3·95d.
Transfer to or from Renewal Account	Cr.£133,495	£257,316	£115,501	£270,086	Cr.£170,716	Cr.£179,722	£145,117	£148,306
Engine power supplied to and by the Company (balance)	Cr.£149,724	Cr.£136,595	Cr.£286,043	Cr.£254,676	Cr. £68,093	Cr. £71,702	Cr. £18,133	Cr. £18,222
Total	£4,059,492	£4,035,257	£3,482,659	£3,702,114	£1,690,376	£1,758,538	£877,476	£929,524

(Continued on next page)

Table 10—Maintenance of Rolling-Stock, Abstract "B," Years 1937 and 1938—*Continued*

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
Per engine	£530	£530	£529	£568	£465	£484	£484	£512
Per engine-mile (steam)	4·28d.	4·39d.	4·84d.	5·30d.	4·08d.	4·33d.	4·26d.	4·78d.
Per cent. on traffic receipts	6·10	6·35	7·15	8·00	6·07	6·61	4·02	4·28
Engine miles run per steam engine per annum	29,761	28,879	26,263	25,740	27,398	26,852	27,271	25,714
LOCOMOTIVES (ELECTRIC)— Repairs and partial renewals	—	—	£139	£275	—	—	—	—
Per engine-mile (electric loco.)	—	—	1·88d.	3·77d.	—	—	—	—
Per engine	—	—	£11	£21	—	—	—	—
Per cent. on traffic receipts	—	—	—	—	—	—	—	—
RAIL MOTOR VEHICLES (OTHER THAN ELECTRIC)— Complete renewals	Cr. £819	—	—	—	—	—	—	—
Repairs and partial renewals	£2,928	£4,450	£39,052	£49,051	£10,846	£10.452	£230	£71
Per mile (rail motor)	9·38d.	16·36d.	4·41d.	5·24d.	2·86d.	2·47d·	2·96d.	7·01d.
Per vehicle (rail motor)	£366	£405	£465	£584	£603	£581	£230	£71
Transfer to or from Renewal Account	£1,706	£1,636	£28,731	£19,321	£4,438	£4,510	£100	£100
Engine power supplied to and by the Company (balance)	—	—	Cr. £8	Cr. £11	—	—	—	—
Total	£3,815	£6,086	£67,775	£68,361	£15,284	£14,962	£330	£171
Per mile (rail motor)	12·23d.	22·37d.	7·66d.	7·31d.	4·03d.	3·54d.	4·25d.	16·89d.
Per vehicle	£477	£553	£807	£814	£849	£831	£330	£171
Per cent. on traffic receipts	0·01	0·01	0·14	0·14	0·05	0·06	—	—
RAIL MOTOR VEHICLES (ELECTRIC) Complete renewals	£313	£22,319	—	—	—	—	£109,238	£386,632
Repairs and partial renewals	£113,909	£125,491	£23,796	£29,589	£10,331	£10,182	£227,025	£250,147
Per vehicle	£457	£468	£220	£271	£517	—	£163	£166
Transfer to or from Renewal Account	£46,851	£21,408	£8,338	£18,731	—	—	Cr. £3,958	Cr.£283,704
Engine power supplied to and by the Company (balance)	—	—	—	—	—	—	£3,374	£3,376
Total	£161,073	£169,218	£32,134	£48,320	£10,331	£10,182	£335,679	£356,451
Per vehicle	£647	£631	£298	£443	£517	—	£241	£236
Per cent. on traffic receipts....	0·24	0·27	0·07	0·10	0·04	0·04	1·54	1·64
NUMBER OF COACHING VEHICLES (PER STATISTICAL RETURN IIc)	23,422	23,541	19,225	19,626	9,021	8,697	6,983	6,933
COACHING VEHICLES COMPLETELY RENEWED (PER STATISTICAL RETURN XI)	670	784	649	428	466	285	154	293
COACHING VEHICLES (other than Rail Motors) — Complete renewals	£714,218	£822,711	£1,163,610	£669,225	£474,888	£446,532	£148,638	£228,444
Repairs and partial renewals....	£1,227,516	£1,198,530	£1,316,128	£1,241,381	£602,288	£622,126	£619,614	£612,069
Per vehicle	£52	£51	£68	£63	£67	£72	£89	£88
Transfer to or from Renewal Account	£195,938	£24,531	Cr.£542,552	Cr. £23,642	Cr.£223,607	Cr.£156,789	£98,197	£6,890
Total	£2,137,672	£2,045,772	£1,937,186	£1,886,964	£853,569	£911,869	£866,449	£847,403

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Table 10—Maintenance of Rolling-Stock, Abstract "B," Years 1937 and 1938—*Continued*

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
Per vehicle	£91	£87	£101	£96	£95	£105	£124	£122
Per cent. on passenger train traffic receipts	7·92	7·56	10·99	10·87	7·43	7·96	5·12	4·99
Number of Merchandise and Mineral Vehicles (per Statistical Return IID)	281,753	285,611	253,912	258,236	83,650	82,453	33,918	33,709
Merchandise and Mineral Vehicles Completely Renewed (per Statistical Return XI)	2,829	3,401	19,736	15,087	5,127	2,807	1,034	901
Merchandise and Mineral Vehicles—								
Complete renewals	£342,322	£464,834	£2,884,951	£2,276,501	£536,871	£313,153	£165,458	£131,417
Repairs and partial renewals	£1,272,226	£1,250,311	£1,662,159	£1,498,338	£492,269	£521,828	£189,089	£196,896
Per vehicle	£4·52	£4·38	£6·55	£5·80	£5·88	£6·33	£5·57	£5·84
Transfer to or from Renewal Account	£557,916	£474,170	Cr.£1,923,201	Cr.£1,232,897	Cr.£279,500	Cr. £22,175	Cr. £9,258	£12,283
Total	£2,172,464	£2,189,315	£2,623,909	£2,541,942	£749,640	£812,806	£345,289	£340,596
Per vehicle	£7·71	£7·67	£10·33	£9·84	£8·96	£9·86	£10·18	£10·10
Per cent. on goods train traffic receipts	5·49	6·00	8·44	8·80	4·58	5·37	7·00	7·17
Total of Abstract	£8,882,333	£8,806,474	£8,443,596	£8,549,840	£3,434,833	£3,625,768	£2,526,358	£2,571,935
Per cent. on traffic receipts	13·34	13·85	17·34	18·49	12·33	13·64	11·56	11·83

(*Continued from page* 11)

have been fully justified. A comparison of net receipts in these three same years is also interesting:—

	1936 £	1937 £	1938 £	Decrease per cent., 1938 with 1936
L.M.S.R. ..	13,559,531	13,865,928	10,803,235	20·33
L.N.E.R. ..	8,797,783	9,631,085	6,025,992	31·51
G.W.R. ..	5,923,212	6,465,102	4,650,244	21·49
S.R.	5,273,322	5,617,087	5,041,023	4·41
	33,553,848	35,579,202	26,520,494	20·96

In this case three of the companies show very heavy percentages losses in net receipts, and only the Southern can regard the figures with anything approaching equanimity. The return on capital shows a sharp decline in the case of all companies as is borne out by the following figures:—

	1937 Per cent.	1938 Per cent.		1937 Per cent.	1938 Per cent.
L.M.S.R.	3·04	2·35	G.W.R. ..	3·49	2·50
L.N.E.R.	2·73	1·69	S.R. ..	3·28	2·90

It will be seen that the G.W.R. no longer holds the premier place, and the Southern now shows the best return on its total capital expenditure.

Comments in respect of results from each separate business (apart from air transport) will be made in subsequent tables. Air transport revenue in the case of all three companies operating air services shows a falling off and this is due to the fact that there has been a merger of some of the railway operated air services with certain other companies operating air services in the same territory. On the London—Belfast—Glasgow service operated by the L.M.S.R. 470,000 miles were covered with a regularity of 98 per cent., and 7,000 passengers and 540,000 lbs. of mails and freight were conveyed. During the summer an experimental direct service between London and Glasgow *via* Liverpool in connection with the Empire Exhibition was arranged. The air services worked by the railway companies themselves still show considerable losses.

Table 4—Receipts in Respect of Railway Working

Both the L.M.S.R. and Southern companies show increases in receipts from passengers and the decreases on the L.N.E.R. and G.W.R. are not heavy. In parcels and mails only the L.M.S.R. shows any falling off. In freight traffic the story is very different and every company shows a decrease in receipts under each head. In consequence the percentage of total traffic receipts obtained from passenger train traffic shows an appreciable rise. Under the heading of miscellaneous receipts the L.M.S.R. and G.W.R. are slightly down, whilst the L.N.E.R. and Southern show slight increases. Taking the table as a whole however every company shows a loss in revenue in comparison with 1937 as is illustrated by the figures below:—

	1937 £	1938 £	Decrease £	Decrease per cent.
L.M.S.R. ..	67,234,080	64,212,115	3,021,965	4·49
L.N.E.R. ..	49,086,681	46,656,115	2,430,566	4·95
G.W.R. ..	28,110,846	26,829,140	1,281,706	4·56
S.R.	22,113,580	22,012,051	101,529	0·46
	166,545,187	159,709,421	6,835,766	4·10

Table 5—Number of and Receipts from Passengers

It will be seen that there has been a reduction in the number of first class passengers, but both the L.M.S.R. and G.W.R. show increases in first class receipts, and in all cases the average receipt per passenger-journey has gone up. There has evidently been some loss of short distance traffic to the roads, and the increase in fares has doubtless helped to increase the average payment per passenger, whilst in the case of the L.M.S.R. the Glasgow exhibition has been a contributing factor. Second class has now entirely dis-

(*Text continued on page* 16)

Table 11—Rolling-Stock Repairs, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
LOCOMOTIVE REPAIRS (Steam)—								
Heavy	2,881	2,514	2,633	2,460	1,176	1,196	697	683
Light	3,519	3,113	1,779	1,870	1,192	1,102	340	343
Total	6,400	5,627	4,412	4,330	2,368	2,298	1,037	1,026
Cost	£3,324,603	£3,421,732	£3,133,565	£3,222,595	£1,455,970	£1,519,374	£709,408	£767,746
LOCOMOTIVE REPAIRS (Electric)—								
Heavy	3	5	—	1	—	—	—	—
Light	7	17	—	1	—	—	—	1
Total	10	22	—	2	—	—	—	1
Cost	—	—	£139	£275	—	—	—	—
RAIL MOTOR VEHICLES (Steam and Oil)—								
Heavy	5	4	25	43	—	—	—	—
Light	2	2	216	247	—	—	2	1
Total	7	6	241	290	—	—	2	1
Cost	£2,928	£4,450	£39,052	£49,051	£10,846*	£10,452*	£230	£71
RAIL MOTOR VEHICLES (Electric)—								
Heavy	85	95	1	26	—	—	971	1,162
Light	723	658	161	98	53	—	741	836
Total	808	753	162	124	53	—	1,725‡	1,998
Cost	£113,909	£125,491	£23,796	£29,589	£10,331	£10,182	£227,025	£250,147
CARRIAGE, &c., REPAIRS—								
Heavy	1,062	706	4,149	3,559	2,634	2,532	1,686	1,665
Light	10,113	10,622	44,547	42,238	14,558	15,546	13,779	13,500
Total	11,175	11,328	48,696	45,797	17,192	18,078	15,488†	15,183†
Cost	£1,227,516	£1,198,530	£1,316,128	£1,241,381	£602,288	£622,126	£619,614	£612,069
WAGON REPAIRS—								
Heavy	24,549	13,400	32,827	24,158	12,222	11,260	2,346	2,416
Light	489,213	464,279	539,177	477,089	226,723	216,657	57,952	52,364
Total	513,762	477,679	572,004	501,247	238,945	227,917	60,298	54,780
Cost	£1,272,226	£1,250,311	£1,662,159	£1,498,338	£492,269	£521,828	£189,089	£196,896

* Includes repairs to rail motor vehicles (oil)
† Includes 23 carriages converted for electric working in 1937 and 18 in 1938.
‡ Includes 13 carriages converted for electric working in 1937

(*Continued on next page*)

Table 11—Rolling-Stock Repairs, Years 1937 and 1938—*Continued*

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
ROLLING-STOCK UNDER AND AWAITING REPAIR AT DECEMBER 31—								
Locomotives (steam)	369*	450*	337	371	344	237	156	112
Per cent. of stock	4·82	5·89	5·12	5·69	9·47	6·53	8·60	6·17
Rail motor vehicles (steam)	—	—	17	8	—	—	1	—
Per cent. of stock	—	—	21·25	10·00	—	—	100	—
Rail motor vehicles (oil)	—	1	—	—	—	—	—	—
Per cent. of stock	—	9·09	—	—	—	—	—	—
Rail motor vehicles (electric)	25	25	23	5	—	—	85	73
Per cent. of stock	10·04	9·33	21·30	4·59	—	—	6·10	4·83
Carriages....	1,160	1,108	707	787	356	350	231	282
Per cent. of stock	6·76	6·44	5·78	6·42	5·73	5·87	4·37	5·49
Other coaching vehicles	418	390	383	328	171	159	39	45
Per cent. of stock	6·67	6·15	5·48	4·46	6·08	5·82	2·30	2·51
Wagons	9,295	7,653	6,551	6,474	3,245	3,697	868	814
Per cent. of stock ..	3·30	2·68	2·58	2·51	3·88	4·48	2·56	2·41

* Includes Diesel oil and oil electric locomotives

(*Continued from page* 14)

appeared on the L.M.S.R., and on the L.N.E.R. suburban lines second class travelling has also disappeared, so that in the case of that company the average receipt per passenger-journey has jumped from 2s. 0·84d. to 10s. 7·51d. Third class passengers have also diminished in numbers, but the L.M.S.R. and Southern have increases in receipts, and all companies show an improvement in the average payment per passenger-journey. Probably the same reasons operate as in the case of first class travel. Under the head of workmen, all companies show increases in receipts, though only the G.W.R. can report an increase in journeys. The slight reduction in travel of only 0·87 per cent. seems to indicate that any increases in charges which have been made have not driven the traffic away from rail.

Under the heading of season tickets the L.N.E.R. shows a small increase in revenue from first class season ticket holders, with, however, a diminution in numbers. The other companies show decreases. Apparently only one solitary second class ticket holder has remained on the L.N.E.R. The bulk of the former second class passengers have now gone to swell the ranks of the third class, who have increased from 108,852 to 143,285. The Southern Company has also increased its revenue from third class season ticket holders.

Table 6—Goods Train Traffic—Tons and Receipts

The extent to which the various classes of traffic have fallen off is shown by the following figures:—

	1937 Tons	1938 Tons	Decrease Tons	Decrease per cent.
Merchandise (excluding classes 1-6)	70,456,871	62,902,069	7,554,802	10·72
Merchandise and minerals (Classes 1-6)	72,735,306	59,235,276	13,500,030	18·56
Coal, Coke, and patent fuel ..	220,220,939	202,241,009	17,979,930	8·16
	No.	No.	No.	
Livestock ..	12,493,625	11,408,012	1,085,613	8·69

It will be seen that the heaviest percentage falling off has taken place in merchandise and minerals in Classes 1-6, and that the lowest percentage reduction in tonnage has taken place in coal, coke, and patent fuel. How much of the decrease is due to recession in trade and how much to diversion to road transport it is impossible to say, but there are certain of the heavier traffics such as bricks and roadstone which are especially susceptible to road competition. The conveyance of livestock by rail still shows a marked falling off and here again road transport has special advantages. Receipts per ton have advanced all round and may be ascribed mainly to the increase in charges made in October, 1937.

Table 7—Originating Freight Traffic

The figures in this table tell the same tale as in the preceding one. Not only are the group tonnages much below those of 1937, but in every instance except originating coal on the G.W.R. they are substantially below 1936. In specific traffics the only increases in tonnage in comparison with 1937 are packed manure on the L.M.S.R. and G.W.R.; oil cake on the L.M.S.R.; cement and lime on the G.W.R.; and gravel and sand, limestone and chalk, and vegetables on the Southern. The iron and steel traffic groups show tremendous reductions and bricks and timber of all descriptions are almost equally affected. All the principal heads of livestock likewise show heavy reductions in the number of heads.

Table 8—Expenditure in Respect of Railway Working

In this table it will be seen that the L.M.S.R. is the only company which has managed to show a reduction in working expenses to compensate to some extent for the reduction in receipts. The figures for each company are as follow:—

	1937 £	1938 £	Increase or decrease £	Increase or decrease per cent.
L.M.S.R. ..	53,597,673	53,355,771	− 241,902	0·45
L.N.E.R. ..	39,540,466	40,541,280	+1,000,814	2·53
G.W.R. ..	21,792,828	22,192,996	+ 400,168	1·84
S.R.	17,243,732	17,736,373	+ 492,641	2·86
	132,174,699	133,826,420	1,651,721	1·25

The economies on the L.M.S.R. have been mainly effected in respect of maintenance of rolling stock and in general charges, of which more will be said later on. In mileage, demurrage, and wagon hire a debit of £1,819 in 1937 has been turned into a credit of £40,576 in 1938. The main economy on the L.N.E.R. has been under the head of compensation. It will be remembered that the payments for personal injury were increased by £100,000 a year ago in respect of the accident at Castlecary. The G.W.R. has saved nearly £50,000 in general charges and about £16,000 in law charges.

The rise in the percentage of expenditure to receipts in respect of railway working in the case of each company is significant:—

	1937	1938		1937	1938
	Per cent.	Per cent.		Per cent.	Per cent.
L.M.S.R.	79·72	83·09	G.W.R. ..	77·52	82·72
L.N.E.R.	80·55	86·89	S.R. ..	77·98	80·58

Table 9—Maintenance of Way and Works

The Southern Company alone shows any increase in the number of miles of line maintained. In actual track renewals the L.M.S.R. and L.N.E.R. renewed 24 and 54 additional miles respectively. Less track renewal was carried out on the G.W.R. and Southern than was the case in 1937. In all cases the cost per mile of track renewal shows a very substantial advance upon the figures of the previous year. Repairs and partial renewals have also cost considerably more than a year ago. The L.N.E.R. and Southern have both spent more on maintenance of roads, bridges, and works than in 1937, and these two companies also show the largest advances in signalling costs and in maintenance of telegraphs and telephones. On the Southern the maintenance of electric track equipment is naturally increasing. All companies have spent a good deal more on the maintenance of stations and buildings. Reserves have been drawn upon to a much greater extent than in 1937 by the L.M.S.R., L.N.E.R., and Southern companies, the G.W.R. being the only company to place anything to reserve. The quantities of ballast, rails, and sleepers used by each company show some variation but not to any very marked degree.

Table 10—Maintenance of Rolling Stock

All companies except the Southern have reduced their stocks of steam locomotives. Electric railmotor vehicles are on the increase except on the G.W.R., where the 20 which were in use in 1937 have disappeared. The Southern has now 1,511 electric railmotor vehicles as compared with

Table 12—Locomotive Running Expenses, Abstract "C" (Summary), Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
TRAIN-MILES (PER STATISTICAL RETURN XIIc)—								
Steam, tender and tank engines	154,981,648	152,348,669	118,838,064	116,743,468	67,410,147	66,497,494	35,679,004	33,514,040
Electric traction	6,126,198	6,668,905	1,441,774	1,775,060	362,154	—	33,133,975	37,355,073
Steam, petrol, &c., rail motors	246,933	228,441	2,117,233	2,279,627	864,931	972,130	18,470	2,367
Total	161,354,779	159,246,015	122,397,071	120,798,155	68,637,232	67,469,624	68,831,449	70,871,480
STOCK OF ENGINES, &C. (PER STATISTICAL RETURN II)—								
Engines	7,688	7,644	6,578	6,520	3,633	3,631	1,814	1,816
Electric power vehicles	249	268	121*	122*	20	—	1,397‡	1,514‡
Petrol power, &c., rail motor vehicles	8	11	84†	84†	18	18	1	1
Total	7,945	7,923	6,783	6,726	3,671	3,649	3,212	3,331
SUPERINTENDENCE (SALARIES AND OFFICE EXPENSES)	£314,412	£316,140	£267,759	£263,709	£114,690	£117,081	£57,910	£58,983
Per train-mile	0·47d.	0·48d.	0·53d.	0·52d.	0·40d.	0·40d.	0·20d.	0·20d.
Per engine, &c.	£39·57	£39·90	£39·48	£39·34	£31·24	£32·09	£18·03	£17·71
WORKING—								
Steam train	£13,190,061	£13,179,029	£10,451,760	£10,521,519	£5,390,482	£5,509,767	£3,041,995	£3,047,645
Per train-mile	20·39d.	20·76d.	20·74d.	21·23d.	18·95d.	19·89d.	20·45d.	21·82d.
Per engine	£1,714	£1,724	£1,569	£1,614	£1,476	£1,517	£1,676	£1,677
Electric train	£421,434	£451,930	£65,336	£89,725	£43,612	£41,875	£1,317,403	£1,527,864
Per train-mile (electric traction)	16·51d.	16·26d.	10·87d.	12·13d.	28·90d.	10·34d.	9·54d.	9·82d.
Per vehicle (electric traction)	£1,692	£1,686	£540	£735	£2,181	£2,326	£943	£1,009
Transfer to or from Renewal Account	Cr. £8,236	Cr. £5,346	£21,005	£1,717	—	—	—	—
Balance of engine power supplied to and by the company	Cr.£483,875	Cr.£446,130	Cr.£788,876	Cr.£746,170	Cr.£207,403	Cr.£209,298	Cr. £52,383	Cr. £52,244
Total of abstract	£13,433,796	£13,495,623	£10,016,984	£10,130,500	£5,341,381	£5,459,425	£4,364,925	£4,582,248
Per train-mile (Total)	19·98d.	20·34d.	19·64d.	20·13d.	18·68d.	19·42d.	15·22d.	15·52d.
Per engine, &c. (Total)	£1,691	£1,703	£1,477	£1,506	£1,455	£1,496	£1,359	£1,376
Per cent. of traffic receipts	20·18	21·23	20·57	21·90	19·18	20·53	19·98	21·08

* Includes 13 electric engines † Includes 80 steam motor vehicles ‡ Includes 3 diesel-electric locomotives

1,816 steam locomotives. Renewals of steam locomotives have been much fewer than in 1937, as is shown below:—

	1937 No.	1938 No.
L.M.S.R. ..	266	92
L.N.E.R. ..	147	91
G.W.R.	150	122
S.R.	—	11
	563	316

The cost of repairs per engine in stock shows an upward tendency, but the average number of engine-miles run per engine in stock is less than a year ago. The Southern has renewed 81 electric railmotor vehicles as compared with 59 in 1937. Maintenance costs of electric stock have increased substantially on the L.N.E.R., but costs per vehicle are still well below the figures of the L.M.S.R. Southern maintenance costs per vehicle are very moderate in comparison.

Both the L.M.S.R. and the L.N.E.R. have added to their stock of coaching vehicles. Complete renewals were greater in the case of the L.M.S.R. and Southern, but both the L.N.E.R. and G.W.R. did substantially less renewal work. Costs per vehicle maintained were less except in the case of the G.W.R. As in the case of coaching stock, the L.M.S.R. and L.N.E.R. have increased their stocks of wagons, but the L.M.S.R. is the only company to have carried out more renewals. In relation to its stock, however, its renewal programmes in both 1937 and 1938 have been very moderate.

(*Text continued on page* 24)

Table 13—Locomotive Running Expenses, Abstract "C," Details, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
STEAM TRAIN WORKING—								
Wages connected with the running of locomotive engines	£7,550,858	£7,497,882	£6,109,712	£6,151,047	£3,333,030	£3,401,155	£1,665,432	£1,667,610
Per train-mile	11·67d.	11·81d.	12·12d.	12·41d.	11·72d.	12·28d.	11·20d.	11·94d.
Per engine	£981	£981	£917	£943	£913	£937	£918	£918
Fuel	£4,885,945	£4,885,862	£3,751,615	£3,785,333	£1,802,838	£1,841,298	£1,218,984	£1,226,346
Per train-mile	7·55d.	7·70d.	7·44d.	7·64d.	6·34d.	6·65d.	8·19d.	8·78d.
Per engine	£635	£639	£563	£581	£494	£507	£672	£675
Water	£327,294	£329,194	£280,108	£277,552	£95,227	£94,159	£71,390	£68,873
Per train-mile	0·51d.	0·52d.	0·56d.	0·56d.	0·33d.	0·34d.	0·48d.	0·50d.
Per engine	£43	£43	£42	£43	£26	£26	£39	£38
Lubricants	£104,469	£107,150	£70,351	£75,014	£38,577	£42,735	£22,663	£23,443
Per train-mile	0·16d.	0·17d.	0·14d.	0·15d.	0·14d.	0·15d.	0·15d.	0·17d.
Per engine	£14	£14	£11	£12	£10	£12	£12	£13
Other stores (including clothing)	£180,653	£217,379	£134,116	£133,601	£77,469	£85,712	£40,104	£36,337
Per train-mile	0·28d.	0·34d.	0·27d.	0·27d.	0·27d.	0·31d.	0·27d.	0·26d.
Per engine	£23	£28	£20	£20	£21	£23	£22	£20
Miscellaneous	£140,842	£141,562	£105,858	£98,972	£43,341	£44,708	£23,422	£23,465
Per train-mile	0·22d.	0·22d.	0·21d.	0·20d.	0·15d.	0·16d.	0·16d.	0·17d.
Per engine	£18	£19	£16	£15	£12	£12	£13	£13
ELECTRICAL TRAIN WORKING—								
Wages of motormen	£107,564	£115,059	£16,428	£19,601	£10,379	£10,320	£279,596	£326,970
Per train-mile (electric traction)	4·21d.	4·14d.	2·73d.	2·65d.	6·88d.	2·55d.	2·02d.	2·11d.
Per vehicle (electric traction)	£432	£429	£136	£161	£519	£573	£200	£216
Electric current	£303,778	£326,673	£47,544	£68,827	£32,830	£31,145	£1,027,546	£1,189,768
Per train-mile (electric traction)	11·90d.	11·75d.	7·91d.	9·31d.	21·75d.	7·69d.	7·44d.	7·64d.
Per vehicle (electric traction)	£1,220	£1,219	£392	£564	£1,642	£1,730	£736	£786
Lubricants	£2,559	£2,386	£314	£166	£163	£165	£4,916	£5,719
Per train-mile (electric traction)	0·10d.	0·09d.	0·05d.	0·02d.	0·11d.	0·04d.	0·04d.	0·04d.
Per vehicle (electric traction)	£10	£9	£3	£1	£8	£9	£3	£4
Other Stores (including clothing)	£7,533	£7,812	£1,050	£1,131	£240	£245	£5,345	£5,407
Per train-mile (electric traction)	0·30d.	0·28d.	0·18d.	0·15d.	0·16d.	0·06d.	0·04d.	0·03d.
Per vehicle (electric traction)	£30	£29	£9	£9	£12	£14	£4	£3

Table 14—Traffic Expenses, Abstract " D," Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
Total traffic receipts per Account No. 10	£66,567,466	£63,562,391	£48,697,432	£46,248,039	£27,851,650	£26,586,563	£21,850,422	£21,739,072
Train mileage per statistical return XIIB	161,224,565	159,263,296	116,049,802	114,333,866	68,314,864	67,504,497	69,958,739	7,198,195
SALARIES AND WAGES—								
Superintendence	£1,233,704	£1,262,586	£1,085,929	£1,128,441	£574,339	£589,930	£371,467	£379,772
Stationmasters and clerks ...	£4,381,422	£4,398,580	£2,583,698	£2,569,094	£1,306,425	£1,313,167	£912,665	£916,180
Signalmen and gatemen ...	£2,006,842	£2,024,782	£1,433,048	£1,452,957	£810,991	£822,290	£517,881	£531,580
Ticket collectors, policemen, porters, &c.	£4,374,493	£4,331,571	£3,099,895	£3,131,765	£2,021,710	£2,043,528	£1,505,138	£1,573,410
Guards	£1,766,168	£1,718,296	£1,189,910	£1,192,741	£724,310	£733,108	£459,864	£477,423
Total	£13,762,629	£13,735,815	£9,392,480	£9,474,998	£5,437,775	£5,502,023	£3,767,015	£3,878,365
Per cent. on total traffic receipts	20·68	21·61	19·29	20·49	19·52	20·69	17·24	17·84
FUEL, LIGHTING, WATER AND GENERAL STORES	£567,960	£563,367	£474,963	£478,773	£214,452	£213,068	£211,385	£225,781
Per cent. on total traffic receipts	0·85	0·89	0·98	1·04	0·77	0·80	0·97	1·04
CLOTHING	£121,710	£124,118	£85,076	£98,834	£65,506	£69,845	£68,888	£66,222
Per cent. on total traffic receipts	0·18	0·20	0·18	0·21	0·24	0·27	0·31	0·30
PRINTING, ADVERTISING, STATIONERY, STAMPS AND TICKETS	£536,020	£554,512	£408,657	£427,865	£230,878	£213,642	£239,344	£265,462
Per cent. on total traffic receipts	0·81	0·87	0·84	0·93	0·83	0·81	1·09	1·22
WAGON COVERS, &C.	£215,847	£185,731	£142,950	£116,916	£56,421	£53,920	£27,452	£23,188
Per cent. on total traffic receipts	0·33	0·29	0·27	0·25	0·20	0·20	0·13	0·11
EXPENSES OF JOINT STATIONS AND JUNCTIONS	£24,461	£22,473	Cr. £16,847	Cr. £16,374	£2,494	£2,513	Cr. £7,810	Cr. £8,806
Per cent. on total traffic receipts	0·04	0·04	0·03	0·04	0·01	0·01	0·04	0·04
CLEANSING, LUBRICATING AND LIGHTING OF VEHICLES	£769,764	£807,119	£491,448	£534,933	£295,402	£309,524	£223,140	£246,347
Per cent. on total traffic receipts	1·16	1·27	1·01	1·16	1·06	1·17	1·02	1·13
SHUNTING EXPENSES (OTHER THAN MECHANICAL)—								
Wages	£1,493,967	£1,491,357	£1,047,735	£1,050,905	£667,570	£684,702	£268,120	£275,679
Other expenses	£19,375	£22,291	£27,611	£26,312	£6,157	£5,811	£4,901	£4,523
Total	£1,513,342	£1,513,648	£1,075,346	£1,077,217	£673,727	£690,513	£273,021	£280,202
Per cent. on total traffic receipts	2·27	2·38	2·21	2·33	2·42	2·59	1·25	1·29
WORKING OF STATIONARY ENGINES, HOISTS, CRANES, &C.	£367,550	£379,609	£224,799	£238,375	£77,032	£81,923	£69,759	£73,156
Per cent. on total traffic receipts	0·55	0·60	0·46	0·52	0·28	0·31	0·32	0·34
RAILWAY CLEARING HOUSE EXPENSES	£191,839	£199,676	£156,987	£162,487	£90,164	£92,904	£45,519	£45,320
Per cent. on total traffic receipts	0·29	0·31	0·32	0·35	0·32	0·35	0·21	0·21
PASSENGER TICKET AGENTS' COMMISSION	£102,452	£107,004	£77,407	£75,815	£39,648	£40,043	£90,351	£89,362
Per cent. on total traffic receipts	0·15	0·17	0·16	0·16	0·14	0·15	0·41	0·41
TRANSHIPMENT BY ROAD VEHICLES	£874,640	£859,998	£514,036	£497,433	£363,341	£359,569	£180,641	£174,197
Per cent. on total traffic receipts	1·31	1·35	1·06	1·07	1·31	1·35	0·83	0·80
MISCELLANEOUS EXPENSES ...	£201,207	£206,038	£145,316	£144,553	£75,190	£76,888	£80,279	£78,250
Per cent. on total traffic receipts	0·30	0·32	0·30	0·31	0·27	0·29	0·37	0·36
COAL, &C., TIPPING EXPENSES	£33,773	£29,999	—	—	—	—	—	—
Per cent. on total traffic receipts	0·05	0·05	—	—	—	—	—	—

(Continued on next page)

Tablo 14—Traffic Expenses, Abstract "D," Years 1937 and 1938—*Continued*

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
TRANSFER TO OR FROM RENEWAL ACCOUNT	£184	Cr. £4,711	£14,380	£9,023	£925	£1,078	Cr. £1,047	Cr. £4,049
Per cent. on total traffic receipts	—	0·01	0·03	0·02	—	—	—	0·02
Total of Abstract	£19,283,378	£19,284,396	£13,186,998	£13,320,848	£7,622,955	£7,707,453	£5,267,937	£5,432,997
Per cent. on total traffic receipts	28·97	30·34	27·08	28·80	27·37	28·99	24·11	24·99
Per train-mile	28·71d.	29·06d.	27·27d.	27·96d.	26·78d.	27·40d.	18·07d.	18·11d.

Table 15—General Charges, Abstract "E," Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
Gross receipts of the whole undertaking (excluding miscellaneous as per Account No. 8)	£75,855,536	£72,452,794	£56,430,244	£53,565,814	£32,586,547	£31,039,727	£25,580,836	£25,468,465
Train mileage per Statistical Return XIIB	161,224,565	159,263,296	116,049,802	114,333,866	68,314,864	67,504,497	69,958,739	71,981,195
DIRECTORS' FEES VOTED BY SHAREHOLDERS	£25,000	£25,000	£21,000	£21,000	£23,713	£23,900	£17,860	£20,000
Per cent. on gross receipts	0·03	0·03	0·04	0·04	0·07	0·08	0·07	0·08
FEES PAID TO AND EXPENSES OF DIRECTORS ON JOINT COMMITTEES NOT INCLUDED IN ABSTRACT "J"	£279	£284	£200	£200	£436	£439	£741	£748
AUDITORS AND PUBLIC ACCOUNTANTS	£4,686	£4,684	£2,639	£2,595	£3,000	£3,000	£2,648	£2,648
Per cent. on gross receipts	0·01	0·01	—	—	0·01	0·01	0·01	0·01
SALARIES OF SECRETARY, GENERAL MANAGER, ACCOUNTANT AND CLERKS	£467,538	£468,311	£434,747	£434,647	£216,714	£217,653	£225,487	£224,160
Per cent. on gross receipts	0·62	0·65	0·77	0·81	0·67	0·70	0·88	0·88
OFFICE EXPENSES OF SECRETARY, GENERAL MANAGER, ACCOUNTANT AND CLERKS	£54,756	£49,819	£53,239	£57,617	£23,752	£24,735	£28,249	£28,081
Per cent. on gross receipts	0·07	0·07	0·09	0·11	0·07	0·08	0·11	0·11
RATING EXPENSES	£19,756	£21,255	£9,050	£7,611	£7,219	£6,310	£7,346	£7,053
Per cent. on gross receipts	0·03	0·03	0·02	0·01	0·02	0·02	0·03	0·03
INSURANCE	£65,799	£61,964	£76,549	£69,247	—	—	£28,473	£28,226
Per cent. on gross receipts	0·09	0·08	0·14	0·13	—	—	0·11	0·11
SUPERANNUATION AND BENEVOLENT FUNDS, PENSIONS, &C.	£1,799,768	£1,580,828	£784,048	£789,222	£863,435	£807,947	£519,848	£521,061
Per cent. on gross receipts	2·37	2·18	1·39	1·47	2·65	2·60	2·03	2·04
SUBSCRIPTIONS AND DONATIONS....	£48,260	£49,495	£5,160	£4,945	£6,258	£6,215	£2,891	£2,831
Per cent. on gross receipts	0·06	0·07	0·01	0·01	0·02	0·02	0·01	0·01
MISCELLANEOUS EXPENSES	£106,602	£120,176	£47,474	£50,511	£29,011	£31,752	£27,833	£29,190
Per cent. on gross receipts	0·14	0·17	0·08	0·10	0·09	0·10	0·11	0·12
Proportion transferred to other accounts	Cr. £217,088	Cr. £206,963	Cr. £140,053	Cr. £139,305	Cr. £151,416	Cr. £149,158	Cr. £104,873	Cr. £109,907
Total of abstract	£2,375,356	£2,174,853	£1,294,053	£1,298,290	£1,022,122	£972,793	£756,503	£754,091
Per cent. on gross receipts	3·13	3·00	2·29	2·42	3·14	3·13	2·95	2·96
Per train-mile	3·54d.	3·28	2·68d.	2·73	3·59d.	3·46	2·60d.	2·51

Table 16—Receipts and Expenses in Connection with Collection and Delivery of Parcels and Goods, Account No. 16, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
GROSS RECEIPTS—	1937	1938	1937	1938	1937	1938	1937	1938
Passenger train traffic	£134,267	£146,448	£116,192	£126,615	£91,240	£92,784	£109,727	£111,387
Goods train traffic	£2,238,502	£2,079,306	£1,234,542	£1,190,718	£935,778	£908,786	£422,578	£421,905
Miscellaneous	£4,507	£5,392	£11,935	£14,702	£11,176	£10,665	£10,670	£1,058
Total	£2,377,276	£2,231,146	£1,362,669	£1,332,035	£1,038,194	£1,012,235	£542,975	£534,350
NO. OF HORSES FOR ROAD VEHICLES, PER STATISTICAL RETURN III	8,154	7,351	2,193	1,734	1,664	1,476	731	602
GOODS AND PARCELS, ROAD VEHICLES, PER STATISTICAL RETURN III—								
Road motors for goods and parcels	3,270	3,454	3,532	3,767	2,324	2,410	655	736
Horse wagons and carts	16,344	16,629	4,783	4,330	2,947	2,930	1,001	934
Miscellaneous	1,255	1,617	1,657	1,835	926	1,061	254	415
Total	20,869	21,700	9,972	9,932	6,197	6,401	1,910	2,085
SUPERINTENDENCE	£47,977	£48,718	£29,259	£28,824	£27,416	£28,315	£4,803	£4,856
Per cent. on gross receipts	2·02	2·18	2·15	2·17	2·64	2·80	0·89	0·91
MAINTENANCE OF BUILDINGS	£35,645	£27,280	£12,372	£12,234	£9,849	£5,767	£2,177	£2,489
Per cent. on gross receipts	1·50	1·22	0·91	0·92	0·95	0·57	0·40	0·47
MAINTENANCE OF MOTOR VEHICLES	£234,712	£333,801	£191,340	£190,648	£175,108	£179,458	£73,478	£120,495
Per motor vehicle	£72	£97	£54	£51	£75	£74	£112	£164
Per cent. on gross receipts	9·87	14·96	14·04	14·31	16·87	17·73	13·53	22·55
MAINTENANCE OF HORSES	£517,351	£492,290	£162,996	£130,417	£119,637	£101,075	£62,281	£53,541
Per horse	£63	£68	£74	£75	£72	£68	£85	£89
Per cent. on gross receipts	21·76	22·07	11·96	9·79	11·52	9·99	11·47	10·02
MAINTENANCE OF HORSE VEHICLES	£120,006	£123,097	£32,136	£28,363	£18,374	£17,367	£9,377	£14,782
Per horse vehicle	£7	£7	£7	£7	£6	£6	£9	£16
Per cent. on gross receipts	5·05	5·52	2·36	2·13	1·77	1·71	1·73	2·76
TRAFFIC EXPENSES	£2,035,333	£1,958,248	£1,201,145	£1,200,638	£874,375	£877,973	£341,832	£342,416
Per cent. on gross receipts	85·61	87·77	88·15	90·14	84·22	86·74	62·95	64·08
AMOUNT PAID FOR HIRED CARTAGE	£437,228	£351,104	£273,006	£222,841	£199,292	£170,654	£158,779	£152,022
Per cent. on gross receipts	18·39	15·74	20·03	16·73	19·19	16·86	29·24	28·45
GENERAL CHARGES	£77,351	£71,098	£29,886	£30,101	£40,344	£40,314	£13,506	£13,355
Per cent. on gross receipts	3·25	3·19	2·19	2·26	3·89	3·98	2·49	2·50
Rates, INCLUDING RATE RELIEF....	£13,349	£10,406	£7,211	£7,950	£3,197	£3,701	£1,124	£1,423
Per cent. on gross receipts	0·57	0·47	0·53	0·60	0·31	0·36	0·21	0·27
LICENCE DUTY	£127,297	£129,132	£108,666	£112,868	£91,265	£93,599	£28,167	£28,211
Per cent. on gross receipts	5·35	5·79	7·97	8·47	8·79	9·25	5·19	5·28
MISCELLANEOUS	£75,249	£75,340	£42,770	£41,962	£35,700	£36,395	£12,295	£8,792
Per cent. on gross receipts	3·17	3·38	3·14	3·15	3·44	3·59	2·26	1·64
Transfer to or from Renewal Account	£77,001	£29,202	£162,057	£138,954	£49,985	£67,219	£10,285	Cr. £41,657
CARTAGE PERFORMED FOR AND BY OTHER COMPANIES	Cr. £959,242	Cr. £847,309	Cr. £486,326	Cr. £504,016	Cr. £366,268	Cr. £362,600	Cr. £185,760	Cr. £179,989
Per cent. on gross receipts	40·35	37·98	35·69	37·84	35·28	35·82	34·21	
TOTAL OF ABSTRACT	£2,839,257	£2,802,407	£1,766,518	£1,641,784	£1,278,274	£1,259,237	£532,344	£520,736
Per cent. on gross receipts	119·43	125·61	129·63	123·26	123·12	124·40	98·04	97·45

Table 17—Receipts and Payments in respect of Running Power Expenses, Abstract "G," Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
Passenger train receipts, per Account No. 10	£26,994,311	£27,076,728	£17,625,031	£17,357,161	£11,489,143	£11,454,000	£16,919,613	£16,987,497
PASSENGER TRAIN TRAFFIC—								
Receipts	£84,038	£84,537	£120,515	£115,830	£76,259	£72,407	£4,558	£4,806
Per cent. on passenger train receipts	0·31	0·31	0·68	0·67	0·66	0·63	0·03	0·03
Payments	£37,475	£36,223	£64,025	£64,362	£12,470	£12,572	£3,340	£3,310
Per cent. on passenger train receipts	0·14	0·13	0·36	0·37	0·11	0·11	0·02	0·02
Goods train receipts, per Account No. 10	£39,573,155	£36,485,663	£31,072,401	£28,890,878	£16,362,507	£15,132,563	£4,930,809	£4,751,575
GOODS TRAIN TRAFFIC—								
Receipts	£95,043	£84,340	£144,573	£156,953	£112,378	£110,786	£41,014	£38,948
Per cent. on goods train receipts	0·24	0·23	0·47	0·54	0·69	0·73	0·83	0·82
Payments	£131,469	£127,144	£60,987	£52,176	£19,890	£17,760	£44,724	£40,956
Per cent. on goods train receipts	0·33	0·35	0·20	0·18	0·12	0·12	0·91	0·86
TOTAL TRAFFIC RECEIPTS, PER ACCOUNT No. 10	£66,567,466	£63,562,391	£48,697,432	£46,248,039	£27,851,650	£26,586,563	£21,850,422	£21,739,072
TOTAL—								
Receipts	£179,081	£168,877	£265,088	£272,783	£188,637	£183,193	£45,572	£43,754
Per cent. on total traffic receipts	0·27	0·27	0·54	0·59	0·68	0·69	0·21	0·21
Payments	£168,944	£163,367	£125,012	£116,538	£32,360	£30,332	£48,064	£44,266
Per cent. on total traffic receipts	0·25	0·26	0·26	0·25	0·12	0·11	0·22	0·24

Table 18—Abstract "H," Mileage, Demurrage and Wagon Hire, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
MILEAGE AND DEMURRAGE—								
Passenger train vehicles—	£	£	£	£	£	£	£	£
Receipts	28,014	37,616	43,108	41,981	4,626	4,978	21,546	20,744
Expenditure	71,924	72,538	19,356	19,081	7,987	4,963	25,848	25,303
Balance	Dr. 43,910	Dr. 34,922	Cr. 23,752	Cr. 22,900	Dr. 3,361	Cr. 15	Dr. 4,302	Dr. 4,559
Goods train vehicles—								
Receipts	72,515	69,003	207,568	178,326	633	565	70,108	66,889
Expenditure	47,997	17,887	9,128	8,972	96,233	81,896	83,660	72,192
Balance	Cr. 24,518	Cr. 51,116	Cr. 198,440	Cr. 169,354	Dr. 95,600	Dr. 81,331	Dr. 13,552	Dr. 5,303
HIRE—								
Passenger train vehicles—								
Receipts	4,873	4,928	11,115	11,268	497	545	873	848
Expenditure	—	—	170	—	—	—	45	30
Balance	Cr. 4,873	Cr. 4,928	Cr. 10,945	Cr. 11,268	Cr. 497	Cr. 545	Cr. 828	Cr. 818
Goods train vehicles—								
Receipts	12,833	19,907	50,736	64,855	5,102	5,589	1,350	—
Expenditure	133	453	116,400	113,288	1,079	2,332	21	32
Balance	Cr. 12,700	Cr. 19,454	Dr. 65,664	Dr. 48,433	Cr. 4,023	Cr. 3,257	Cr. 1,329	Dr. 32
TOTAL—								
Receipts	118,235	131,454	312,527	296,430	10,858	11,677	93,877	88,481
Expenditure	120,054	90,878	145,054	141,341	105,299	89,191	109,574	97,557
Balance	Dr. 1,819	Cr. 40,576	Cr. 167,473	Cr. 155,089	Dr. 94,441	Dr. 77,514	Dr. 15,697	Dr. 9,076

Table 19—Receipts and Expenditure in respect of Steamboats, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
GROSS RECEIPTS—								
Passengers	£551,876	£508,189	£477,011	£444,963	£146,661	£151,986	£936,253	£988,283
Per cent. of receipts	36·58	36·31	54·55	54·75	43·23	43·64	63·90	64·18
Parcels and Mails	£159,137	£162,227	£41,133	£39,743	£47,109	£48,415	£269,360	£286,316
Per cent. of receipts	10·55	11·59	4·70	4·89	13·89	13·90	18·39	18·59
Merchandise	£637,594	£585,019	£301,488	£276,872	£119,234	£124,024	£168,106	£167,138
Per cent. of receipts	42·26	41·80	34·47	34·06	35·14	35·61	11·47	10·86
Livestock	£111,581	£98,831	£3,647	£3,231	£9,777	£8,698	£3,993	£3,763
Per cent. of receipts	7·40	7·06	0·42	0·40	2·88	2·50	0·27	0·25
Miscellaneous	£48,389	£45,227	£51,228	£47,965	£16,501	£15,169	£87,520	£94,287
Per cent. of receipts	3·21	3·24	5·86	5·90	4·86	4·35	5·97	6·12
Total	£1,508,577	£1,399,493	£874,507	£812,774	£339,282	£348,292	£1,465,232	£1,539,787
EXPENDITURE—								
Salaries and wages	£489,795	£476,967	£328,180	£324,920	£109,770	£110,931	£384,269	£383,603
Per cent. of expenditure	40·67	39·99	39·76	39·11	34·38	34·15	34·07	33·59
Fuel	£170,214	£180,816	£144,302	£150,270	£56,183	£60,534	£188,573	£193,810
Per cent. of expenditure	14·13	15·16	17·48	18·09	17·60	18·64	16·72	16·97
Stores, lubricants, water, &c.	£25,963	£25,918	£21,785	£25,000	£7,212	£7,907	£36,622	£38,977
Per cent. of expenditure	2·16	2·17	2·64	3·01	2·26	2·44	3·25	3·41
Renewals	£59,621	£39,935	—	—	—	—	£23,402	—
Per cent. of expenditure	4·95	3·35	—	—	—	—	2·08	—
Repairs	£91,237	£73,636	£67,208	£77,538	£52,208	£26,004	£146,149	£167,653
Per cent. of expenditure	7·58	6·17	8·14	9·34	16·35	8·01	12·96	14·68
Insurance	£20,776	£20,153	£24,100	£23,024	£7,082	£8,095	£16,848	£16,988
Per cent. of expenditure	1·72	1·69	2·92	2·77	2·22	2·49	1·49	1·49
Harbour fees and Light dues	£145,916	£150,468	£56,513	£51,930	£42,867	£40,069	£86,776	£77,116
Per cent. of expenditure	12·12	12·61	6·84	6·25	13·42	12·34	7·70	6·75
General Charges	£35,408	£33,524	£16,469	£16,652	£10,430	£10,248	£41,779	£46,707
Per cent. of expenditure	2·94	2·81	2·00	2·01	3·26	3·16	3·70	4·09
Miscellaneous	£74,981	£72,630	£83,413	£81,607	£16,898	£16,394	£69,989	£85,263
Per cent. of expenditure	6·23	6·09	10·10	9·82	5·29	5·05	6·21	7·46
TOTAL WORKING EXPENSES	£1,113,912	£1,074,047	£741,970	£750,941	£302,650	£280,182	£994,407	£1,010,117
Per cent. of expenditure	92·50	90·04	89·88	90·40	94·78	86·28	88·18	88·44
Transfer to or from Renewal Account	£90,378	£118,767	£83,510	£79,761	£16,681	£44,571	£133,283	£131,998
Per cent. of expenditure	7·50	9·96	10·12	9·60	5·22	13·72	11·82	11·56
TOTAL EXPENDITURE	£1,204,290	£1,192,814	£825,480	£830,702	£319,331	£324,753	£1,127,690	£1,142,115
Per cent. on gross receipts....	79·83	85·23	94·39	102·21	94·12	93·24	76·96	74·16
BALANCE—								
Profit	£304,287	£206,679	£49,027	Loss £17,928	£19,951	£23,539	£337,542	£397,672
Per cent. on gross receipts	20·17	14·77	5·61	—	5·88	6·76	23·04	25·84

(*Continued from page* 18)

Cost of maintenance per wagon has dropped on the L.N.E.R., but increased rather markedly on the G.W.R.

Transfers to and from the renewals funds play an important part in this abstract, and the position of each company in this respect is as follows:—

	1937		1938	
	Transfers to	With-drawals	Transfers to	With-drawals
	£	£	£	£
L.M.S.R. ..	802,411	133,495	779,061	—
L.N.E.R. ..	152,570	2,465,753	308,138	1,256,539
G.W.R. ..	4,438	673,823	4,510	358,686
S.R. ..	243,414	13,216	167,579	283,704

Table 11—Rolling Stock Repairs

All companies have executed fewer repairs to steam locomotives but the cost of repairs has increased all round. Repairs to electric railmotor vehicles have been fewer on the L.M.S.R. and L.N.E.R. but costs have risen. On the Southern the number of repairs and the repairs bill have both been greater. In coaching stock only the G.W.R. has a heavier repairs bill than in 1937. All companies have done fewer wagon repairs but both the G.W.R. and the Southern have higher repairs bills. The L.M.S.R. and L.N.E.R. have an increase in the number of locomotives under or awaiting repair, and the L.N.E.R. and Southern more carriages. In wagons the G.W.R. alone has a larger number out of traffic.

Tables 12 and 13—Locomotive Running Expenses

Apart from the Southern, all companies have reduced their train- and engine-mileage and the increase on the Southern has been naturally under the head of electric traction. Costs of steam train working, both per locomotive- and per train-mile have gone up, but in electric working results vary. The G.W.R. records electric train costs in its accounts but has apparently run no electric train-mileage, and it has been assumed for the purposes of this table that the costs incurred in 1938 under the head of electric train working were on account of traction with "Any other form of power." The main causes of increase in costs in steam train working were higher wages and higher cost of fuel, but notwithstanding these factors the L.M.S.R. actually reduced its wages bill by **£53,000** and its coal bill by **£83**. It was explained at the annual meeting of that company that although increased cost of coal for the same tonnage as was used in 1937 would have meant an extra charge of **£201,750,** savings were effected of **£153,104** in respect of less mileage run and of **£48,729** in respect of a lower consumption of coal per mile. In electric train working the L.N.E.R. has paid **£28,000** more for current and the cost per train-mile has increased from 7·91d. to 9·31d. Owing to its additional electric train-mileage, the Southern has paid **£47,000** more in wages of motormen and **£162,000** more for electric current, and the cost per mile for current has risen from 7·44d. to 7·64d.

Table 14—Traffic Expenses

The increases granted in salaries and wages in 1937 are brought out most prominently in this table and all companies show increases in expenses under each head of salaries and wages except the L.M.S.R., which has effected economies under the headings of ticket collectors, policemen, porters, &c.; guards and shunters. Fuel, &c., costs are much the same except on the Southern where an increase of **£14,000** is reported. The L.N.E.R. clothing bill is also up by **£14,000** and is nearly **30** per cent. higher than it was two years ago. Printing, &c., shows an upward tendency except on the G.W.R., but all companies have spent less on wagon covers. On the other hand the cost of cleansing, lubricating and lighting of vehicles has increased, and in this item wages figure prominently. Costs of working stationary engines, &c., are also up, and, except on the Southern, Railway Clearing House expenses; transhipment by road vehicles has cost rather less. Taking the abstract as a whole the expenditure has absorbed a substantially higher percentage of traffic receipts in the case of each company than it did in 1937.

Table 15—General Charges

The main feature in this table is the saving of £219,000 made by the L.M.S.R. under the heading of superannuation and benevolent funds, pensions, &c. This has been due to a review of the position of the actuarial liability of the superannuation fund, and the lower charge to this abstract will

Table 20—Receipts and Expenditure in respect of Canals, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
Miles of Navigation, per Statistical Return V.	536	535	246	246	210	210	55 chains	55 chains
Gross receipts	£115,992	£120,926	£36,626	£34,959	£13,688	£13,862	£2,376	£1,750
Per mile of navigation	£216	£226	£149	£142	£65	£66	£3,456	£2,545
Expenditure—								
Superintendence	£3,298	£3,208	£374	£405	£207	£208	£168	£145
Wages of toll clerks, lock-keepers, &c.	£11,897	£11,249	£4,491	£4,426	£420	£445	£167	£165
Maintenance of canals and water supply	£113,970	£108,635	£39,406	£42,267	£29,941	£32,315	£1,015	£434
Rates, including rate relief	£7,763	£5,755	£2,141	£1,418	£530	£86	£20	£26
Miscellaneous	£11,910	£11,486	£1,671	£1,838	£1,266	£1,260	£6	£5
General charges	£5,297	£5,171	£965	£997	£668	£703	£29	£29
Transfer to or from Renewal Account	Cr. £4,372	£4,286	£100	£105	—	—	—	—
Total	£149,763	£149,790	£49,148	£51,456	£33,032	£35,017	£1,405	£804
Per mile of navigation	£279	£280	£200	£209	£157	£167	£2,044	£1,169
Per cent. on gross receipts	129	124	134	147	241	253	59	46
Balance—								
Profit	—	—	—	—	—	—	£971	£946
Loss	£33,771	£28,864	£12,522	£16,497	£19,344	£21,155	—	—

continue until such time as new actuarial circumstances may require a revision. On the G.W.R. a saving of **£55,000** has also been effected in respect of superannuation fund expenses. The L.N.E.R. has introduced into Parliament this session a scheme for a consolidated superannuation fund, the solvency of which is guaranteed by the company, and it is expected that some increase in the annual charge against revenue will be incurred in consequence.

Table 16—Receipts and Expenses in Connection with Collection and Delivery of Parcels and Goods

Whilst in all cases receipts and expenses have both diminished, the Southern Company is still the only one which continues to show a profit on its collection and delivery business. It will be noted that mechanisation is still proceeding, the number of horses being reduced and the number of road motors increased. The cost of maintenance of motors has increased substantially on the L.M.S.R. and Southern, and costs per vehicle are much higher than in 1937. The cost of maintenance per horse is a little higher except on the G.W.R. and the Southern has spent a good deal more on the maintenance of horse vehicles. In traffic expenses the L.M.S.R. has saved **£77,000.** The bill for hired cartage is down, but rather more has been paid for licence duty. Other expenses remain about the same as a year ago. All companies except the Southern have carried sums to reserve for renewals. If the cost of maintenance of motor vehicles shown in Table 21 is taken into account in connection with this table the adjusted figures for each company are as follow:—

	1937	1938		1937	1938
	£	£		£	£
L.M.S.R.	93	124	G.W.R. ..	80	78
L.N.E.R.	60	56	S.R. ..	117	170

Table 17—Running Power Receipts and Payments

Receipts and payments in respect of running powers remain very much the same in the case of passenger traffic. In goods traffic, L.M.S.R. receipts have dropped by **£11,000** and payments by **£4,000.** L.N.E.R. receipts have increased

(*Text continued on page* 28)

Table 21—Receipts and Expenditure in respect of Road Transport, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
GROSS RECEIPTS:	1937	1938	1937	1938	1937	1938	1937	1938
Passenger Services— Passengers	£252,978	£254,344	£108,769	£111,387	—	—	—	—
Other Receipts	£897	£881	£383	£379	—	—	—	—
Goods Services	£154,535	£147,807	£92,486	£91,732	£72,646	£69,523	£23,703	£24,625
Hire of Vehicles	—	£334	—	—	—	—	—	—
Miscellaneous	£480	£480	£106	£98	£580	£554	—	—
TOTAL	£408,890	£403,846	£201,744	£203,596	£73,226	£70,077	£23,703	£24,625
EXPENDITURE:								
Superintendence	£10,430	£10,701	£3,491	£3,955	£2,164	£2,069	£147	£141
Maintenance of Buildings	£4,639	£4,329	£2,186	£2,104	£258	£245	£67	£71
Maintenance of Motor Vehicles	£68,663	£93,486	£19,772	£20,939	£9,658	£9,068	£3,196	£4,697
Maintenance of Horses	£2,800	£2,310	£1,216	£1,168	£195	£230	—	—
Maintenance of Horse Vehicles	£376	£320	£350	£224	£44	£36	—	—
Traffic Expenses	£193,754	£192,435	£93,321	£92,444	£35,021	£32,961	£11,252	£10,495
Hire of Vehicles....	£326	£277	£5,334	£6,581	£149	—	£374	£54
General Charges	£5,120	£5,002	£2,615	£2,636	£2,332	£2,311	£455	£528
Rates	£1,021	£1,036	£499	£527	£3	£19	£36	£41
Licence Duty	£19,140	£19,285	£7,882	£7,727	£5,004	£4,690	£1,224	£1,099
Miscellaneous	£18,229	£19,318	£9,197	£8,745	£1,235	£1,039	£378	£267
Road Transport for and by other Railway Companies and Undertakings	Cr. £3,178	Cr. £4,886	Cr. £242	Cr. £419	—	—	Cr. £63	Cr. £126
Transfer to or from Renewal Account	£18,305	Cr. £7,793	£17,219	£17,137	£3,315	£3,650	£318	Cr. £1,541
TOTAL	£339,625	£335,820	£162,840	£163,768	£59,378	£56,318	£17,384	£15,726
Per cent. of gross receipts	83·06	83·16	80·73	80·44	81·09	80·34	73·35	63·86
BALANCE								
Profit	£69,265	£68,026	£38,904	£39,828	£13,848	£13,759	£6,319	£8,899
Loss	—	—	—	—	—	—	—	—

Table 22—Receipts and Expenditure in Respect of Docks, Harbours, and Wharves, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
GROSS RECEIPTS—								
Harbour and light dues	£82,375	£89,161	£26,779	£23,235	£33,389	£33,267	£89,095	£86,113
Per cent. of receipts	7·47	9·05	0·96	0·94	1·49	1·67	6·94	7·06
Dock dues on ships	£85,110	£79,831	£512,135	£461,299	£493,878	£457,929	£306,322	£295,825
Per cent. of receipts	7·72	8·10	18·33	18·71	22·03	22·99	23·87	24·27
Dock dues on goods	£138,606	£120,401	£307,393	£261,297	£464,177	£410,828	£80,267	£68,605
Per cent. of receipts	12·57	12·22	11·00	10·60	20·70	20·62	6·25	5·63
Dock dues on passengers	£2,353	£1,806	£547	£450	£7,932	£7,537	£25,018	£23,382
Per cent. of receipts	0·21	0·18	0·02	0·02	0·35	0·38	1·95	1·92
Wharf and pier dues	£21,608	£21,806	£132,963	£125,760	£8,101	£7,003	£25,254	£24,110
Per cent. of receipts	1·96	2·21	4·76	5·10	0·36	0·35	1·97	1·98
Dock railways	£189,310	£169,798	£504,598	£439,206	£123,149	£99,941	£69,142	£68,143
Per cent. of receipts	17·17	17·23	18·06	17·81	5·49	5·02	5·39	5·59
Cranage and other services	£525,235	£443,522	£998,286	£840,061	£955,361	£805,517	£493,986	£466,930
Per cent. of receipts	47·64	45·01	35·73	34·07	42·61	40·44	38·50	38·31
Graving docks	£8,591	£9,216	£43,731	£40,665	£10,419	£12,199	£64,408	£48,175
Per cent. of receipts	0·78	0·94	1·56	1·65	0·47	0·61	5·02	3·95
Warehousing	£7,716	£11,031	£45,738	£59,561	£10,684	£14,507	£17,178	24,985
Per cent. of receipts	0·70	1·12	1·64	2·42	0·48	0·73	1·34	2·05
Rents	£24,093	£21,687	£95,933	£95,350	£76,013	£87,125	£57,915	£61,206
Per cent. of receipts	2·19	2·20	3·43	3·87	3·39	4·37	4·51	5·02
Miscellaneous	£17,589	£17,189	£125,944	£118,485	£59,025	£56,117	£54,657	£51,422
Per cent. of receipts	1·59	1·74	4·51	4·81	2·63	2·82	4·26	4·22
Total	£1,102,586	£985,448	£2,794,047	£2,465,369	£2,242,128	£1,991,970	£1,283,242	£1,218,896
EXPENDITURE—								
Superintendence	£43,472	£43,278	£73,907	£68,567	£57,899	£57,775	£14,701	£16,064
Per cent. of expenditure	4·07	4·28	2·90	2·88	3·05	3·23	1·63	1·82
Maintenance	£160,433	£207,239	£481,030	£445,743	£430,506	£473,707	£134,975	£148,018
Per cent. of expenditure	15·03	20·51	18·89	18·71	22·66	26·47	14·93	16·79
Dredging	£127,523	£128,771	£115,381	£122,879	£65,563	£713,64	£79,874	£90,546
Per cent. of expenditure	11·95	12·74	4·53	5·16	3·45	3·99	8·84	10·26
Operating expenses	£641,586	£546,219	£1,463,344	£1,339,820	£1,036,842	£953,458	£499,663	£477,914
Per cent. of expenditure	60·11	54·05	57·47	56·24	54·58	53·27	55·28	54·18
Rates, including Rate Relief	£34,146	£32,122	£57,705	£46,855	£83,712	£54,402	£27,640	£31,778
Per cent. of expenditure	3·20	3·18	2·27	1·96	4·41	3·04	3·06	3·60
General charges	£31,906	£28,906	£53,575	£51,765	£84,817	£83,265	£40,871	£40,584
Per cent. of expenditure	2·99	2·86	2·10	2·17	4·46	4·65	4·52	4·60
Miscellaneous	£37,990	£34,766	£126,967	£113,240	£81,008	£86,124	£54,879	£55,911
Per cent. of expenditure	3·56	3·44	4·99	4·76	4·26	4·81	6·07	6·34
Transfer to or from Suspense Account	Cr. £9,717	Cr. £10,765	£174,287	£193,580	£59,399	£9,747	£51,195	£21,292
Per cent. of expenditure	0·91	1·06	6·85	8·12	3·13	0·54	5·67	2·41
Total	£1,067,339	£1,010,536	£2,546,196	£2,382,449	£1,899,746	£1,789,842	£903,798	£882,107
Per cent. on gross receipts	96·80	102·55	91·13	96·63	84·73	89·85	70·43	72·37
Net receipts from docks, harbours and wharves	£35,247	Loss £25,088	£247,851	£82,920	£342,382	£202,128	£379,444	£336,789

Table 23—Receipts and Expenditure in Respect of Hotels and of Refreshment Rooms and Cars where Catering is carried on by the Company, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
RECEIPTS—								
Total receipts from hotels and sale of provisions, &c., in the refreshment rooms and cars	£3,080,014	£3,080,430	£2,073,970	£2,060,966	£767,014	£773,246	£147,518	£135,617
EXPENDITURE—								
Salaries and wages	£650,204	£669,701	£362,135	£378,707	£148,351	£151,958	£21,849	£21,628
Per cent. of expenditure	23·84	24·36	18·98	19·64	20·41	20·92	16·80	17·55
Per cent. on gross receipts	21·11	21·74	17·46	18·38	19·34	19·65	14·81	15·95
Provisions, wines, and spirits consumed	£1,328,463	£1,307,917	£1,057,656	£1,054,245	£421,656	£414,482	£61,538	£58,895
Per cent. of expenditure	48·72	47·57	55·42	54·67	58·01	57·05	47·30	47·80
Per cent. on gross receipts	43·13	42·46	51·00	51·15	54·97	53·61	41·72	43·43
Maintenance of hotels and refreshment rooms and fittings, furniture, &c., of refreshment cars	£394,736	£304,789	£224,968	£227,447	£47,008	£46,385	£18,165	£14,798
Per cent. of expenditure	14·47	11·08	11·79	11·80	6·47	6·38	13·96	12·01
Per cent. on gross receipts	12·82	9·89	10·85	11·03	6·13	6·00	12·31	10·92
Heating and lighting of hotels and refreshment rooms	£108,976	£111,843	£58,259	£61,939	£20,450	£22,269	£6,121	£5,631
Per cent. of expenditure	4·00	4·07	3·05	3·21	2·81	3·06	4·71	4·57
Per cent. on gross receipts	3·54	3·63	2·81	3·01	2·66	2·88	4·1	4·15
Rents	£46,121	£45,794	£38,594	£38,735	£22,680	£22,576	—	—
Per cent. of expenditure	1·69	1·67	2·02	2·01	3·12	3·11	—	—
Per cent. on gross receipts	1·50	1·49	1·86	1·88	2·96	2·92	—	—
Rates	£67,714	£66,328	£37,987	£37,208	£13,213	£13,883	£2,271	£2,276
Per cent. of expenditure	2·48	2·41	1·99	1·93	1·82	1·91	1·75	1·84
Per cent. on gross receipts	2·20	2·15	1·83	1·80	1·72	1·80	1·54	1·68
Licence Duty	£8,626	£8,979	£7,467	£7,156	£3,887	£3,962	£365	£342
Per cent. of expenditure	0·32	0·33	0·39	0·37	0·54	0·55	0·28	0·28
Per cent. on gross receipts	0·28	0·29	0·36	0·35	0·51	0·51	0·25	0·25
General Charges	£55,752	£57,172	£35,433	£36,074	£12,176	£12,000	£3,341	£3,312
Per cent. of expenditure	2·04	2·08	1·86	1·87	1·67	1·65	2·57	2·69
Per cent. on gross receipts ...	1·81	1·86	1·71	1·75	1·59	1·55	2·27	2·44
Miscellaneous	£191,415	£193,153	£121,430	£132,496	£37,436	£38,991	£11,904	£11,578
Per cent. of expenditure	7·02	7·02	6·36	6·87	5·15	5·37	9·15	9·40
Per cent. on gross receipts	6·21	6·27	5·85	6·43	4·88	5·04	8·07	8·54
Transfer to or from Suspense Account	Cr. £125,002	Cr. £16,157	Cr. £35,418	Cr. £45,624	—	—	£4,529	£4,757
TOTAL EXPENDITURE	£2,727,005	£2,749,519	£1,908,511	£1,928,383	£726,857	£726,506	£130,083	£123,217
Per cent. of receipts	88·54	89·26	92·02	93·57	94·76	93·96	88·19	90·87
Balance—								
Profit	£353,009	£330,911	£165,459	£132,583	£40,157	£46,740	£17,435	£12,400
Percentage of profit to gross receipts	11·46	10·74	7·98	6·43	5·24	6·04	11·81	9·13

(*Continued from page* 25)

by £12,000 and payments have dropped by nearly £9,000. The figures of the other two companies do not show any very marked change compared with 1937.

Table 18—Mileage, Demurrage, and Wagon Hire

The L.M.S.R. has earned £9,000 more from mileage and demurrage on passenger train vehicles, and has paid £30,000 less in respect of goods train vehicles, whilst the L.N.E.R. has received £30,000 less from the same source. The G.W.R. and Southern Companies have paid £14,000 and £11,000 less respectively in respect of goods train vehicles. The L.M.S.R. and L.N.E.R. have received respectively £7,000 and £14,000 more from the hire of goods train vehicles. On balance the L.M.S.R. is £42,000 better off, the L.N.E.R. credit is reduced by £12,000, whilst the debits of the G.W.R. and Southern are less by £17,000 and £6,000 respectively.

Table 19—Receipts and Expenditure in Respect of Steamboats

Two companies, the L.M.S.R. and L.N.E.R., show a drop in receipts, the G.W.R. and Southern have increases of £9,000 and £75,000 respectively. Most of the Southern increase is in respect of passengers and parcels, and mails. In expenses the L.M.S.R. has saved £20,000 in renewals and £18,000 in repairs, but has transferred £28,000 more to the renewals fund. Its profit is reduced by nearly £100,000. L.N.E.R. expenses are £5,000 more than in 1937, notwithstanding a loss of £62,000 in receipts, and the steamship undertaking shows a loss for the year of nearly £18,000. Although the G.W.R. has saved £26,000 on repairs, it has carried £28,000 more to the renewals fund, and the profit for the year shows little change. The Southern has spent nothing on renewals, and its total expenditure is increased by only £15,000, and its profits are increased by £60,000, the ratio of working

Table 24—Mileage of Lines Open for Traffic and Receipts per Route Mile, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
MILEAGE OF LINES OPEN FOR TRAFFIC (PER STATISTICAL RETURN 1A)—								
Lines owned by the Company, including Company's share of Lines Jointly Owned other than those included in Abstract "J"—								
Length of road	6,866	6,842	6,353	6,337	3,774	3,774	2,133	2,126
Total miles reduced to single track	13,303	13,270	11,446	11,447	6,468	6,470	4,108	4,107
Sidings reduced to single track	5,988	5,977	5,334	5,339	2,593	2,584	1,273	1,280
Total of single track (including sidings)	19,291	19,247	16,780	16,786	9,061	9,054	5,381	5,387
Lines leased or worked—								
Length of road	3	3	12	12	7	7	30	30
Total miles reduced to single track	4	4	25	25	8	8	31	31
Sidings reduced to single track	1	1	1	1	4	4	6	6
Total of single track (including sidings)	5	5	26	26	12	12	37	37
TOTAL—								
Length of road	6,869	6,845	6,365	6,349	3,781	3,781	2,163	2,156
Total miles reduced to single track	13,307	13,274	11,471	11,472	6,476	6,478	4,139	4,138
Sidings reduced to single track	5,989	5,978	5,335	5,340	2,597	2,588	1,279	1,286
Total of single track (including sidings)	19,296	19,252	16,806	16,812	9,073	9,066	5,418	5,427
PASSENGER TRAIN RECEIPTS. PER ACCOUNT No. 10	£26,994,311	£27,076,728	£17,625,031	£17,357,161	£11,489,143	£11,454,000	£16,919,613	£16,987,497
Per route mile	£3,930	£3,956	£2,769	£2,734	£3,039	£3,029	£7,822	£7,879
GOODS TRAIN RECEIPTS. PER ACCOUNT No. 10	£39,573,155	£36,485,663	£31,072,401	£28,890,878	£16,362,507	£15,132,563	£4,930,809	£4,751,575
Per route mile	£5,761	£5,330	£4,882	£4,550	£4,327	£4,002	£2,280	£2,204
TOTAL TRAFFIC RECEIPTS. PER ACCOUNT No. 10	£66,567,466	£63,562,391	£48,697,432	£46,248,039	£27,851,650	£26,586,563	£21,850,422	£21,739,072
Per route mile	£9,691	£9,286	£7,651	£7,284	£7,366	£7,031	£10,102	£10,083
TOTAL RAILWAY RECEIPTS. PER ACCOUNT No. 10	£67,234,080	£64,212,115	£49,086,681	£46,656,115	£28,110,846	£26,829,140	£22,113,580	£22,012,051
Per route mile	£9,788	£9,381	£7,712	£7,349	£7,435	£7,096	£10,224	£10,210

expenses to receipts being less than 75 per cent. The L.M.S.R. is constructing a new diesel engined vessel for its Stranraer—Larne service, and the ss. *Princess Maud*, now running in that service, is to be converted from coal to oil fuel burning.

Table 20—Receipts and Expenditure in Respect of Canals

There is very little change to report either on the receipts or the expenditure side. The L.M.S.R. loss on the year's working is £5,000 less, and the L.N.E.R. loss £4,000 more than a year ago. Once again the Southern has managed to secure a small profit on its canal working.

Table 21—Receipts and Expenditure in Respect of Road Transport

It is hardly necessary to comment on this table, as the figures for 1938 approximate so closely to those of the previous year. All companies continue to earn profits, but as the capital expenditure incurred in providing the services is not shown in the accounts the return on capital is not ascertainable. The great bulk of road transport in which the railway companies have a financial interest is conducted by independent companies to which the railways have subscribed capital, and in the L.N.E.R. report it is stated that the investment with omnibus companies has earned a return of 14·22 per cent., and with goods haulage companies

Table 25—Stock of Coaching Vehicles, Number of Passengers Carried, and Number of Season Ticket Holders, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
NUMBER OF PASSENGER CARRIAGES (PER STATISTICAL RETURN II)—								
Steam	16,780	16,789	12,155	12,179	6,170	5,967	3,897	3,618
Electric	621	678	195	198	60	—	2,784	3,032
Rail motor	8	11	84	84	18	18	1	1
Total	17,409	17,478	12,434	12,461	6,248	5,985	6,682	6,651
NUMBER OF SEATS OR BERTHS (PER STATISTICAL RETURN II)								
Steam—								
First	114,990	113,327	77,363	76,188	39,076	40,245	35,337	33,077
Second....	1,684	—	45,270	936	—	—	264	468
Third	896,216	908,091	541,503	599,796	319,702	306,563	165,159	151,794
Electric	43,430	46,869	11,880	11,944	2,680	—	202,793	217,483
Rail motor	380	542	4,907	4,907	1,056	1,056	44	44
Total	1,056,700	1,068,829	680,923	693,771	362,514	347,864	403,597	402,866
NUMBER OF PASSENGERS CONVEYED (PER STATISTICAL RETURN XIII)—								
Excluding season ticket holders	330,461,503	308,662,863	213,817,204	196,050,050	116,304,989	109,074,895	245,849,681	236,455,741
Estimated number of journeys by season ticket holders	129,085,200	125,562,000	93,490,800	94,431,600	41,454,600	39,729,600	132,864,600	134,116,200
Total	459,546,703	434,224,863	307,308,004	290,481,650	157,759,589	148,804,495	378,714,281	370,571,941
Per carriage	26,397	24,844	24,715	23,656	25,250	24,863	56,677	55,717
Per seat	435	406	451	419	435	428	938	920
NUMBER OF OTHER COACHING VEHICLES—								
Post Office vans	83	82	33	28	33	33	22	22
Luggage, parcel, milk, fruit, and brake vans	2,524	2,478	1,328	1,309	1,284	1,239	1,143	1,290
Fish vans and trucks	812	802	3,815	4,280	363	363	—	—
Carriage trucks	1,631	1,749	509	476	248	243	79	38
Horse boxes	948	943	1,225	1,194	744	695	382	377
Miscellaneous	272	288	73	71	139	157	70	67
Total	6,270	6,342	6,983	7,358	2,811	2,730	1,696	1,794
Total coaching vehicles, including electric stock and rail motor vehicles	23,679	23,820	19,417	19,819	9,059	8,715	8,378	8,445

a return of 5·12 per cent. The Great Western return from investments in road transport companies is now nearly 9 per cent.

Table 22—Receipts and Expenditure in Respect of Docks, Harbours, and Wharves

Decreases are reported by all companies in nearly every item of dock revenue except warehousing, and the total loss in receipts was £760,320, equal to 10·24 per cent. Reductions in expenditure have been made by all companies in varying degree. The L.M.S.R. spent £47,000 more on maintenance, but saved £95,000 in operating expenses. The L.N.E.R. saved £164,000, including £35,000 on maintenance and £124,000 on operating, but the transfer to reserve was increased by £19,000. The G.W.R., although spending £43,000 more on maintenance, saved £83,000 in operating expenses and £29,000 in rates, and transferred £50,000 less to reserve, and the Southern, whilst spending more on maintenance and dredging, saved £22,000 in operating expenses and carried £30,000 less to reserve. On the L.M.S.R. a profit of £35,000 in 1937 was turned into a loss of £25,000 in 1938, and on the L.N.E.R. profits were reduced by £165,000, on the G.W.R. by £140,000, and on the Southern by £43,000.

Table 23—Receipts and Expenditure in Respect of Hotels, Refreshment Rooms, and Restaurant Cars

On the L.M.S.R. revenue increased by less than £500. The G.W.R. earned £6,000 more, but the L.N.E.R. and Southern record decreases of £13,000 and £12,000 respectively. As regards expenditure, on the L.M.S.R. an increase of £20,000 in salaries and wages was balanced by a decrease of a similar amount on provisions, wines, and spirits. On maintenance £90,000 less was spent, but only £16,000 was taken from the renewals fund as against £125,000 in 1937, and the profit for the year was reduced by £22,000. The L.N.E.R. spent £16,000 more in salaries and wages and £11,000 more in miscellaneous expenses, and profit dropped by £33,000. The G.W.R. expenses remained the same as in the previous year, and profits were increased by the additional earnings of £6,000. The Southern saved £7,000 in expenditure, and net revenue fell by only £5,000.

Table 24—Mileage of Line and Receipts per Route-Mile

The L.M.S.R. records a decrease of 44 miles in track-mileage, and the G.W.R. a decrease of 7 miles. On the L.N.E.R. and Southern, track-mileage increased by 6 and

Table 26—Stock of Goods Train Vehicles and the Tonnage of Merchandise and Mineral Traffic Conveyed, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
Number of Merchandise and Mineral Wagons (per Statistical Return IId)—								
Open	144,883	147,811	105,930	106,623	48,182	47,385	23,076	22,771
Covered	51,436	51,220	39,058	41,031	24,387	23,787	6,128	6,349
Special	3,444	3,450	7,167	7,951	2,062	2,318	716	751
Rail and timber (including twin trucks)	7,177	7,732	14,018	14,452	2,426	2,367	585	548
Mineral	61,883	62,509	77,724	78,625	1,225	1,215	1,504	1,443
Total	268,823	272,722	243,897	248,682	78,282	77,072	32,009	31,862
Number of Originating Tons conveyed (Excluding Coal and Coke). (Per Statistical Return XIV.)								
Tons	43,727,419	36,978,689	38,789,450	32,590,903	18,136,905	14,636,198	4,547,692	4,107,448
Per wagon (excluding mineral)	211	176	233	192	235	193	149	135
Number of Cattle Trucks (per Statistical Return IId)	7,436	7,272	5,258	4,884	3,088	3,070	962	915
Heads of Originating Live Stock. (Per Statistical Return XIV.)—								
Number	4,147,753	3,887,319	3,003,238	2,754,091	1,480,246	1,269,050	472,177	395,992
Per wagon	558	535	571	564	479	413	491	433
Number of Brake Vans (per Statistical Return IIe)	5,494	5,617	4,757	4,670	2,280	2,311	947	932
Number of Railway Service Vehicles and Horses for Shunting (per Statistical Return IIe)—								
Coal coke, ash, and sand wagons	9,247	8,903	7,713	7,585	4,561	4,572	140	140
Ballast wagons	2,796	3,361	1,681	1,627	3,509	3,475	819	789
Other wagons, &c.	2,300	2,244	2,511	2,520	1,506	1,498	762	769
Total	14,343	14,508	11,905	11,732	9,576	9,545	1,721	1,698
Horses for shunting	127	124	202	160	23	21	28	24

9 miles respectively. Earnings per route-mile show little change in respect of passenger train traffic, but rather heavy decreases in goods train traffic and, except on the Southern, in total railway receipts per route-mile.

Table 25—Stock of Coaching Vehicles

The L.M.S.R. and L.N.E.R. have added to their stocks of carriages and seats, whilst the G.W.R. and Southern record decreases under both heads. The number of passengers conveyed per vehicle and per seat per annum has declined in the case of all companies, but the Southern continues to show much the best results. The Chairman of that company had something to say about overcrowding at the annual meeting and pointed out that out of 371,000 passengers entering the six London termini of the Southern Railway daily, no fewer than 243,000 or nearly two-thirds of the total arrive between 7 a.m. and 10 a.m. It is a problem which will take a good deal of solving.

Table 26—Stock of Goods Train Vehicles

Both the L.M.S.R. and L.N.E.R. have increased their stocks of wagons, but falling tonnages have reduced the average number of tons conveyed per wagon per annum very considerably, and although the G.W.R. and Southern have fewer wagons than they had a year ago, their tonnages per wagon are also down. The head of livestock conveyed per cattle wagon has also diminished. Service vehicles and shunt horses both show a decrease in numbers.

Table 27—Train and Engine Mileage and Receipts per Train-Mile

All companies except the G.W.R. show slight increases in coaching train-miles run by the companies' engines, and pas-

Table 27—Train and Engine Mileage and Receipts per Train-Mile, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937	1938	1937	1938	1937	1938	1937	1938
A. Miles run in relation to the Company's Traffic Receipts. Total Train-miles (per Statistical Return XII)								
Coaching	103,104,982	104,366,896	69,804,107	70,307,099	43,446,586	43,515,942	62,637,292	64,833,831
Goods	57,872,276	54,686,913	46,028,801	43,823,858	25,046,555	24,115,791	7,413,907	7,234,229
Total	160,977,258	159,053,809	115,832,908	114,130,957	68,493,141	67,631,733	70,051,199	72,068,060
B. Miles run in relation to the Company's Expenditure. Total Train-miles (per Statistical Return XII)								
Coaching	103,140,273	104,427,374	69,961,410	70,461,934	43,335,008	43,438,700	62,623,104	64,820,359
Goods	58,084,292	54,835,922	46,088,392	43,871,932	24,979,856	24,065,797	7,335,635	7,160,836
Total	161,224,565	159,263,296	116,049,802	114,333,866	68,314,864	67,504,497	69,958,739	71,981,195
C. Miles run by the Company's Engines (per Statistical Return XII). Total Train-miles								
Coaching	102,471,127	103,668,285	73,611,299	74,299,075	43,333,062	43,077,088	61,696,017	63,901,266
Goods	58,883,652	55,577,730	48,785,772	46,499,080	25,304,170	24,392,536	7,135,432	6,970,214
Total	161,354,779	159,246,015	122,397,071	120,798,155	68,637,232	67,469,624	68,831,449	70,871,480
Shunting Miles—								
Coaching	7,550,281	7,409,811	4,601,819	4,664,010	2,950,714	2,954,673	2,267,687	2,073,861
Goods	40,814,590	37,187,532	32,777,414	30,519,508	21,256,368	20,329,443	6,789,741	6,543,340
Other Miles (Assisting Light, &c.)	25,241,078	24,489,810	16,615,146	15,953,538	7,946,800	7,736,048	4,831,913	4,760,346
Total engine miles	234,960,728	228,333,168	176,391,450	171,935,211	100,791,114	98,489,788	82,720,790	84,249,027
Percentage train-miles of total engine miles	68·67	69·74	69·39	70·26	68·10	68·50	83·21	84·12
Passenger Train Receipts. Per Account No. 10	£26,994,311	£27,076,728	£17,625,031	£17,357,161	£11,489,143	£11,454,000	£16,919,613	£16,987,497
Per train-mile	5s. 2·84d.	5s. 2·27d.	5s. 0·60d.	4s. 11·25d.	5s. 3·47d.	5s. 3·17d.	5s. 4·83d.	5s. 2·88d.
Goods Train Receipts. Per Account No. 10	£39,573,155	£36,485,663	£31,072,401	£28,890,878	£16,362,507	£15,132,563	£4,930,809	£4,751,575
Per train-mile	13s. 8·11d.	13s. 4·12d.	13s. 6·02d.	13s. 2·22d.	13s. 0·79d.	12s. 6·60d.	13s. 3·62d.	13s. 1·63d.
Total Traffic Receipts	£66,567,466	£63,562,391	£48,697,432	£46,248,039	£27,851,650	£26,829,140	£21,850,422	£21,739,072
Per train-mile	8s. 3·24d.	7s. 11·91d.	8s. 4·90d.	8s. 1·25d.	8s. 1·59d.	7s. 11·21d.	6s. 2·86d.	6s. 0·40d.

senger train receipts per train-mile show only small reductions. Although all companies have run fewer goods train-miles, the drop in goods train receipts has been in greater ratio and the earnings per train-mile have fallen rather heavily. In total traffic receipts per train-mile the L.N.E.R. still shows the highest figure due to its preponderating proportion of freight earnings.

Table 28—Summary of Financial Results Secured

This table shows that the L.M.S.R. has been unable to pay anything on its 4 per cent. preference stock (1923), and on its ordinary stock, amounting in all to a capital of over £135,000,000. Last year £3,033,396 was paid on these stocks. On the L.N.E.R. net revenue was £500,000 below the figure of 1932 and nearly £200,000,000 of preference and ordinary stock has had to go without a dividend. On the G.W.R. the dividend on ordinary stock has only been at the rate of ½ per cent. as compared with 4 per cent. in 1937, and this has only been possible after appropriating £100,000 from the contingency fund. The Southern has managed to pay the full dividend of 5 per cent. on its preferred ordinary stock, but the deferred stock, which received 1½ per cent. in 1937, gets nothing. A dismal picture! What of the future? Will the international situation become less threatening? Will the new trade agreements bring about any revival in industry? Will the "square deal," if brought about, bring additional gain to the depleted coffers of the railway companies? One can only live in hope, but meanwhile in 1939 heavy weekly decreases in railway receipts are being reported and at the end of the first two months of the year they amount to a loss of £1,488,000.

Table 28—Summary of Financial Results Secured, Years 1937 and 1938

	L.M.S.R.		L.N.E.R.		G.W.R.		Southern	
	1937 £	1938 £	1937 £	1938 £	1937 £	1938 £	1937 £	1938 £
Total expenditure on Capital Account (No. 4)	456,684,343	459,285,651	352,589,512	355,750,167	185,390,751	186,363,713	171,495,577	173,589,283
Gross receipts from business carried on by the Company (No. 8)	75,855,536	72,452,794	56,430,244	53,565,814	32,586,547	31,039,727	25,580,836	25,468,465
Revenue expenditure on businesses carried on by the Company (No. 8)	61,989,608	61,649,559	46,799,159	47,539,822	26,121,445	26,389,483	19,963,749	20,427,442
Net receipts of businesses carried on by the Company (No. 8)	13,865,928	10,803,235	9,631,085	6,025,992	6,465,102	4,650,244	5,617,087	5,041,023
"J" Joint Lines—Company's proportion of Net revenue (No. 8)	154,509	290,555	441,841	610,126	145,949	144,318	Dr. 42,388	Dr. 47,422
Miscellaneous receipts net (No. 8)	2,149,900	2,118,272	1,020,152	993,049	1,090,562	1,085,543	1,237,503	1,219,724
Miscellaneous charges	1,814,061	1,866,542	985,636	976,000	815,108	836,352	260,078	271,421
Total net income (No. 8)	14,356,276	11,345,520	10,107,442	6,653,167	6,886,505	5,043,753	6,552,124	5,941,904
Appropriation to contingency fund	—	—	150,000	—	—	—	—	—
Appropriation from contingency fund	—	—	—	—	—	100,000	—	—
Appropriation to new works	—	—	—	—	100,000	—	—	—
Interest on loans and debenture stocks (No. 9)	4,439,170	4,439,170	4,222,274	4,220,487	1,649,832	1,649,848	1,943,167	1,943,167
Dividends on guaranteed and preference stocks (No. 9)	8,474,383	6,869,024	5,717,667	2,430,552	3,344,699	3,343,749	2,751,278	2,751,278
Balance after payments of preference dividends (No. 9)	1,442,723	37,326	17,501	2,128	1,791,974	150,156	1,857,679	1,247,459
DIVIDENDS ON ORDINARY STOCK (No. 9)—								
Interim	Nil	Nil	Nil	Nil	214,648	Nil	551,732	275,866
Rate per cent.	Nil	Nil	Nil	Nil	½	Nil	Preferred 2	Preferred 1
Final	1,428,037	Nil	Nil	Nil	1,502,541	214,649	1,299,952	1,103,464
Rate per cent.	1½	Nil	Preferred Nil	Preferred Nil	3½	½	Preferred 3	Preferred 4
	—	—	Deferred Nil	Deferred Nil	—	—	Deferred 1½	Deferred Nil
Total	1,428,037	Nil	Nil	Nil	1,717,189	214,649	1,851,684	1,379,330
Rate per cent.	1½	Nil	Preferred Nil	Preferred Nil	4	½	Preferred 5	Preferred 5
			Deferred Nil	Deferred Nil			Deferred 1½	Deferred Nil
Surplus	14,686	37,326	17,501	2,128	74,785	—	5,995	—
Deficit	—	—	—	—	—	64,493	—	131,871
Brought forward from previous year	79,083	93,769	66,425	83,926	76,793	151,578	220,809	226,804
Carried forward to subsequent year	93,769	131,095	83,926	86,054	151,578	87,085	226,804	94,933

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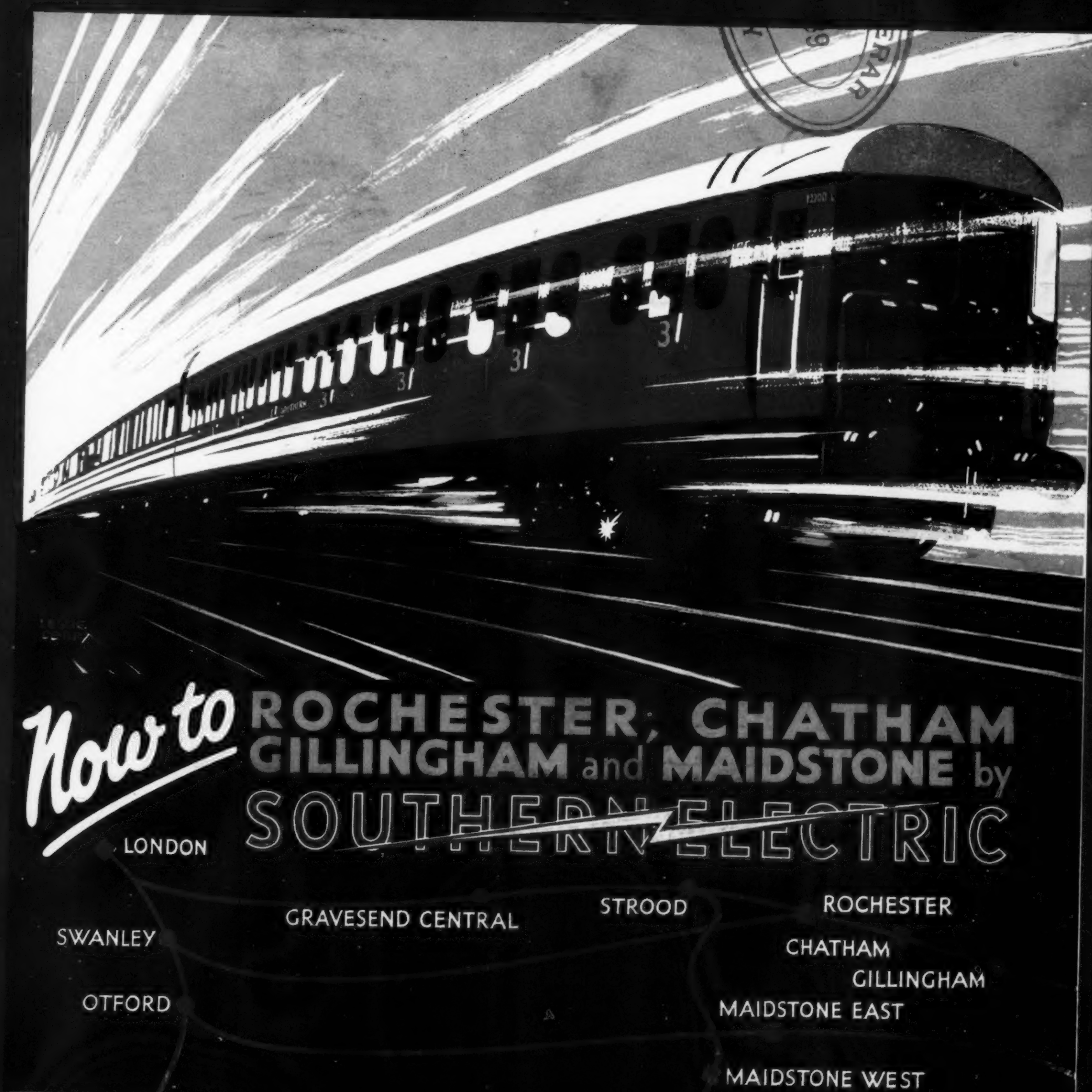

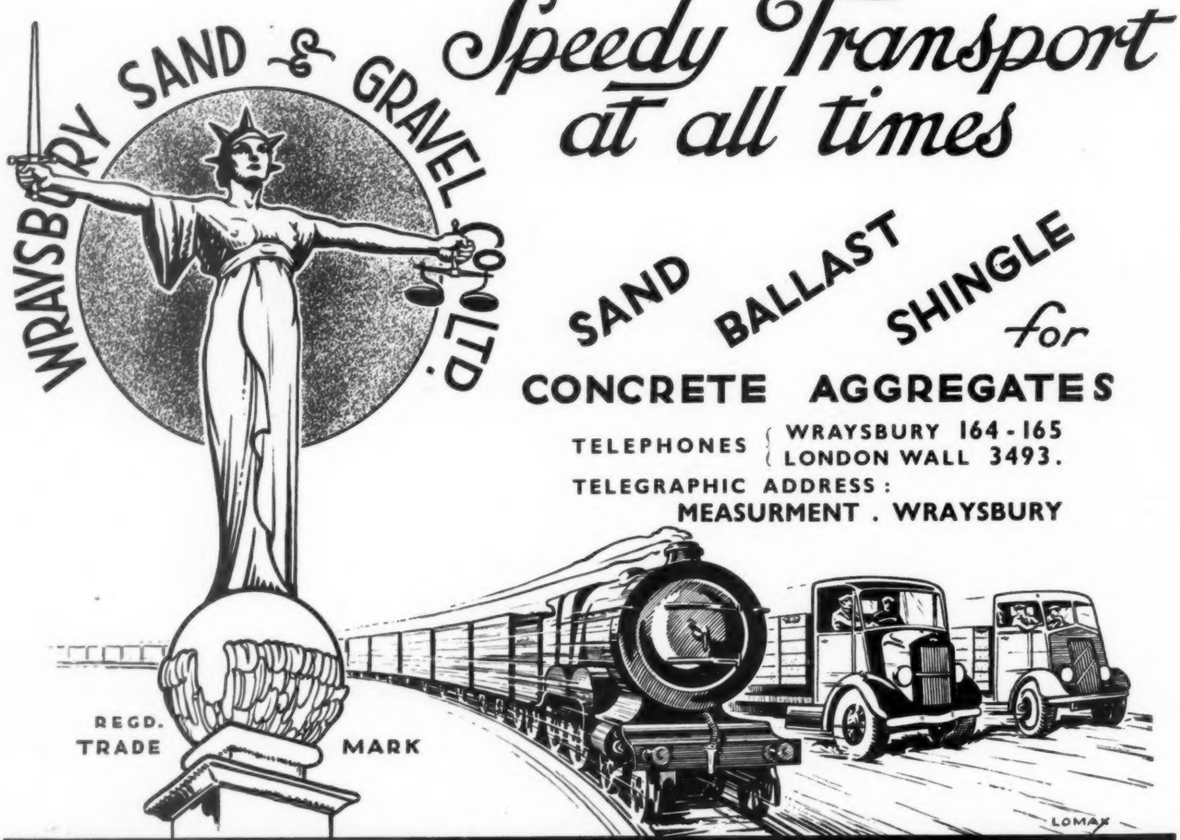
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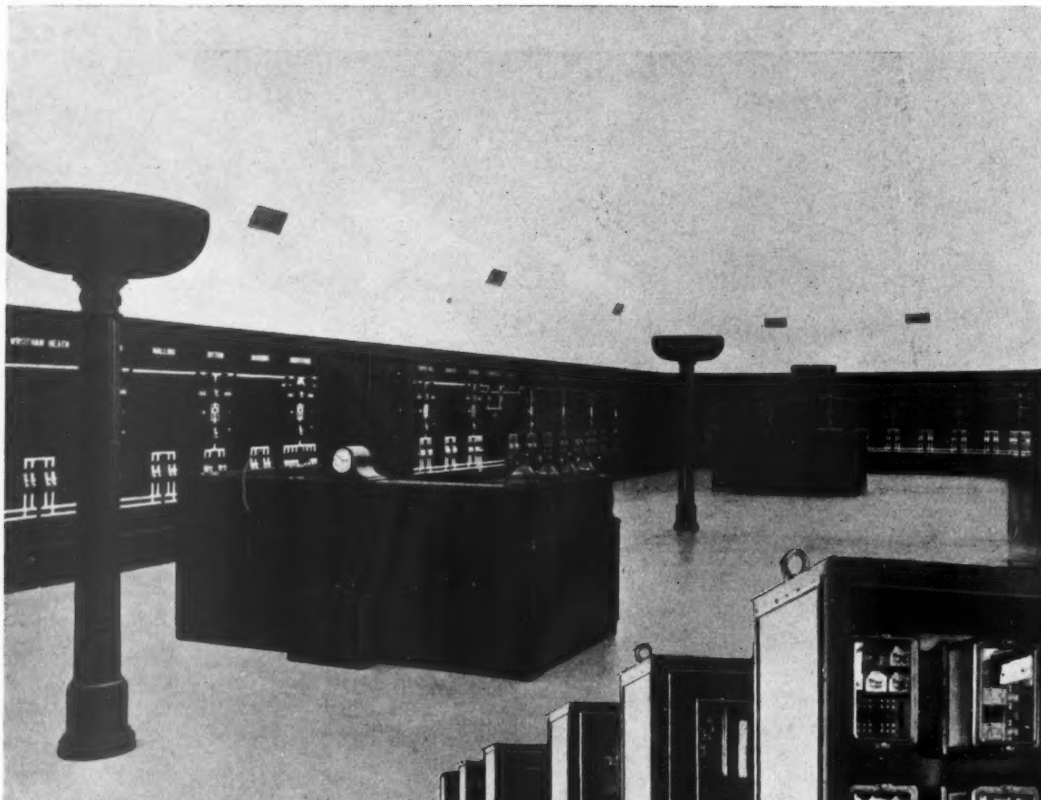

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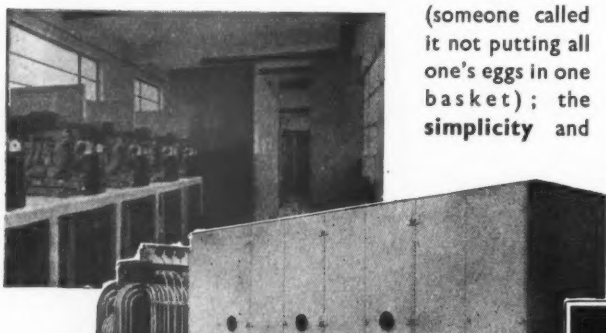

(*Left*) A typical substation interior and one of the six 600 kW. 650 V. equipments supplying the Wirral system.

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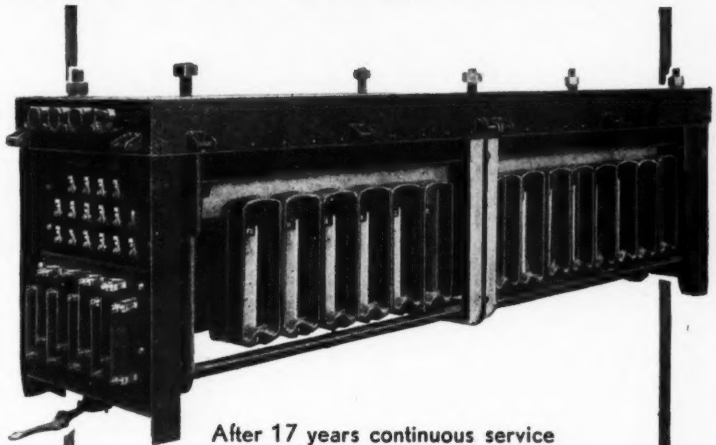

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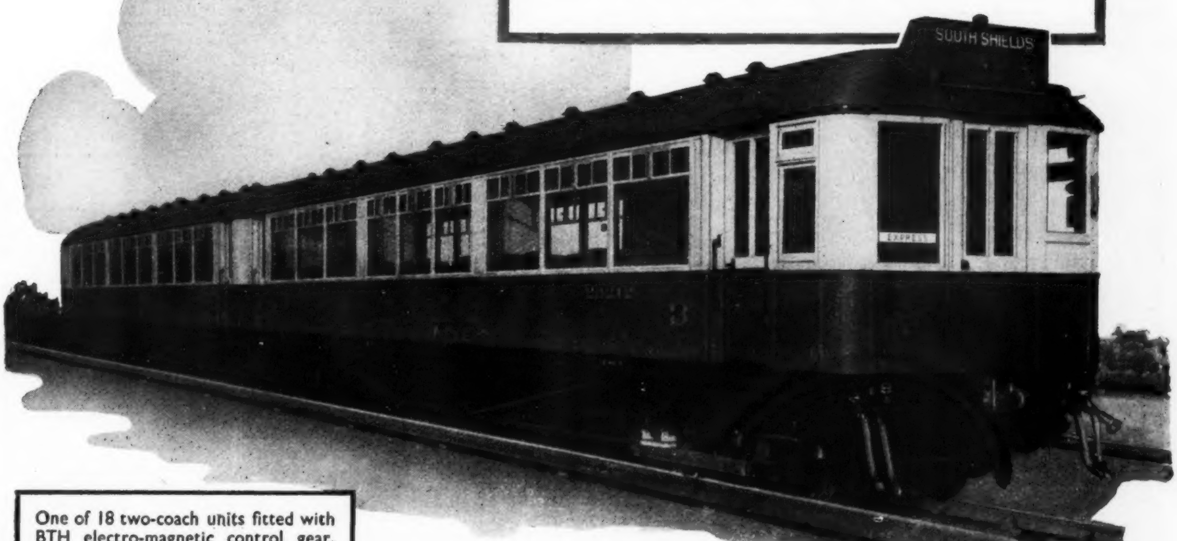

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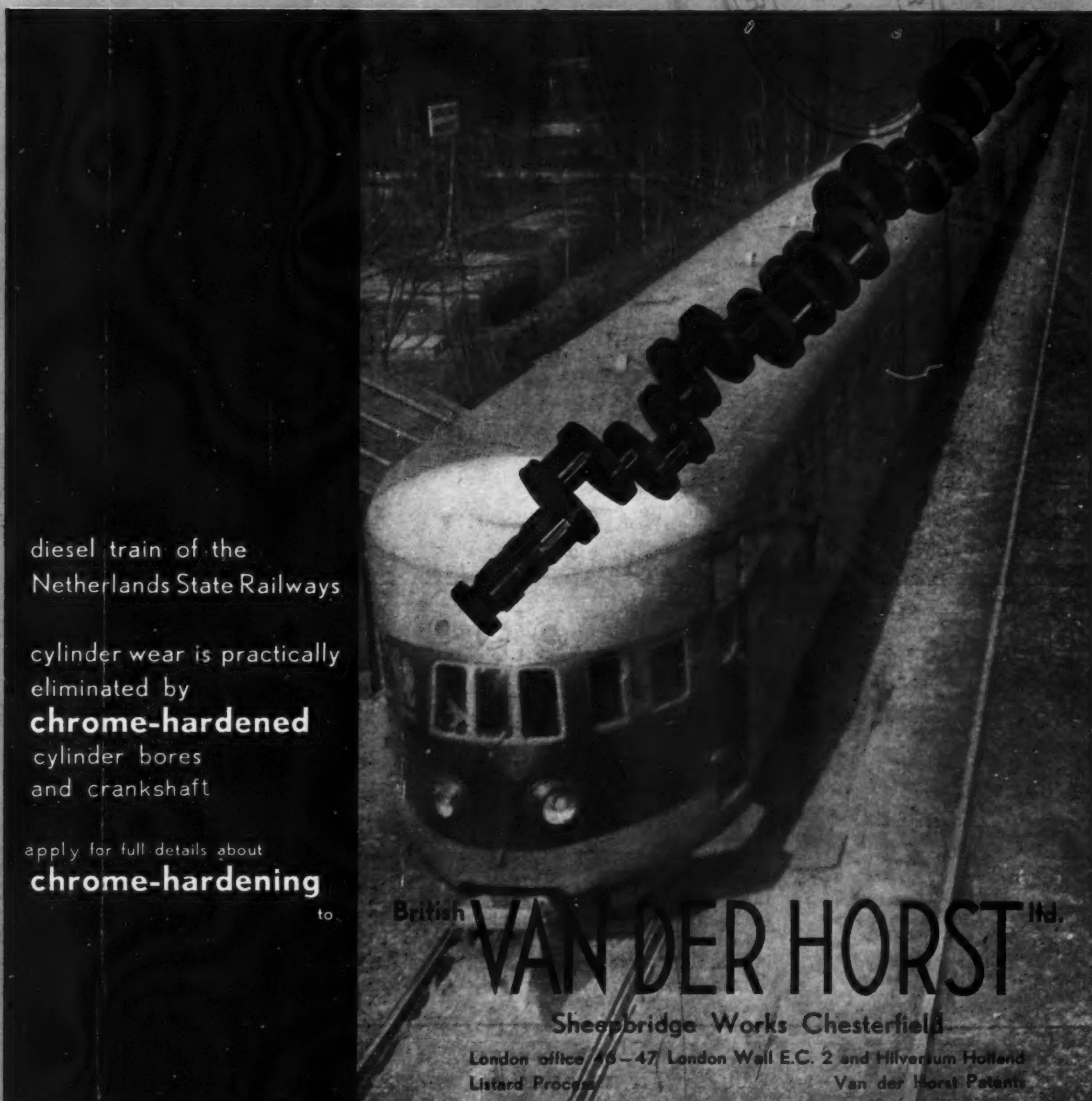

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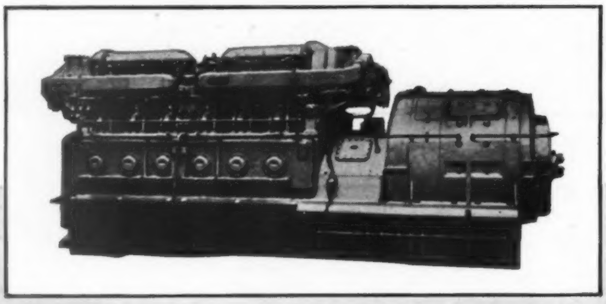

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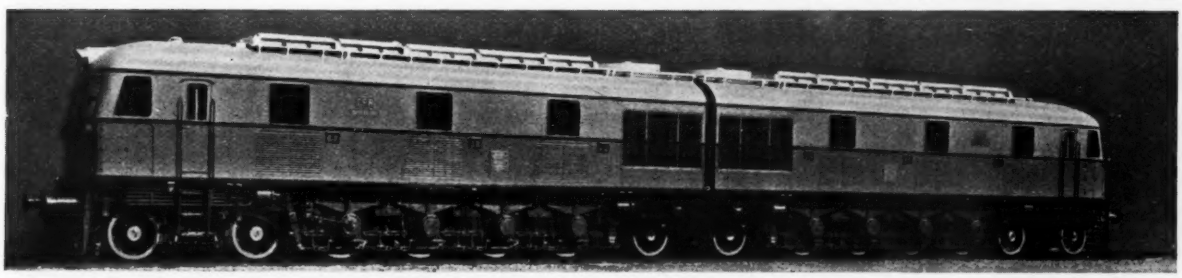

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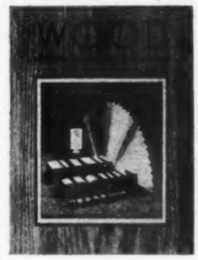

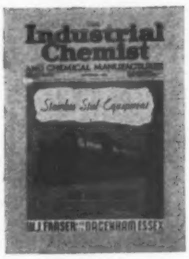

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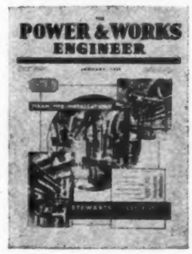

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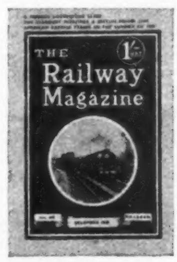

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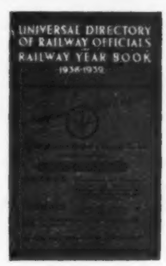

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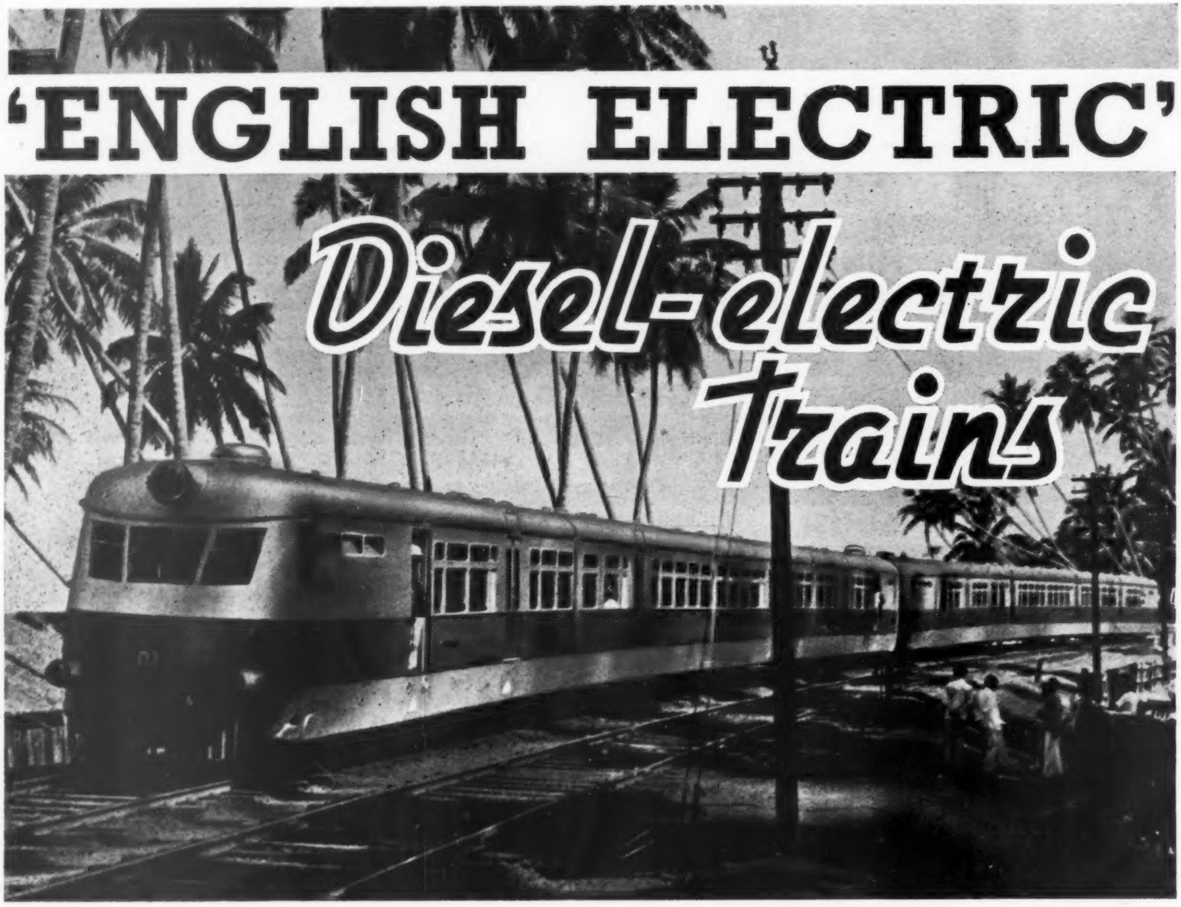

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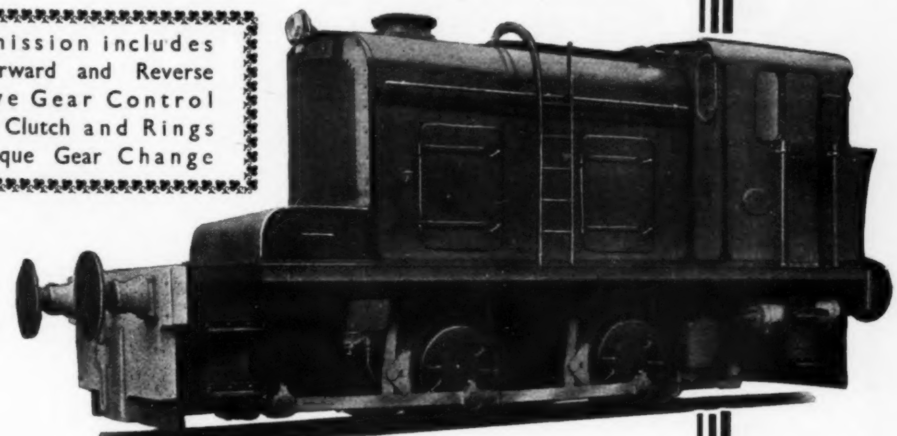

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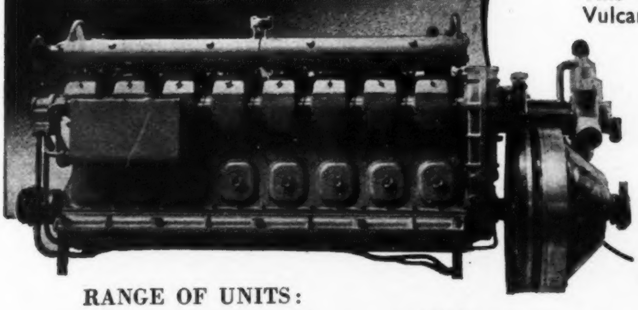

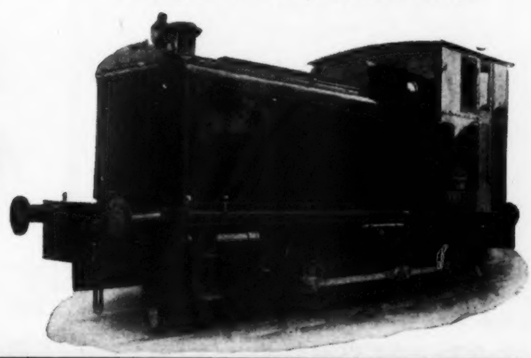

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RESIGNALLING OF VICTORIA STATION, S.R. (*with Folding Plate*), pp. 1063-1068
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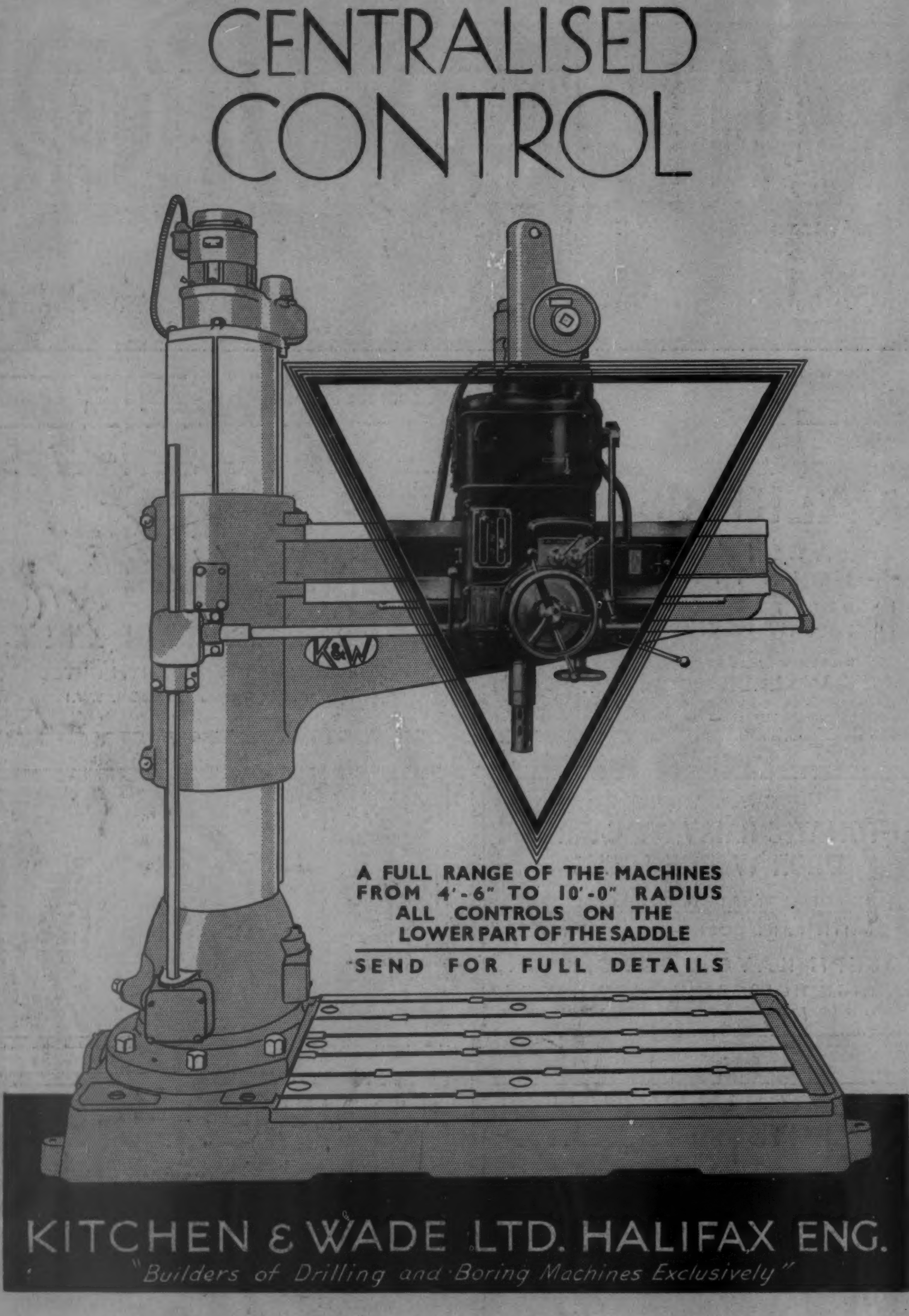
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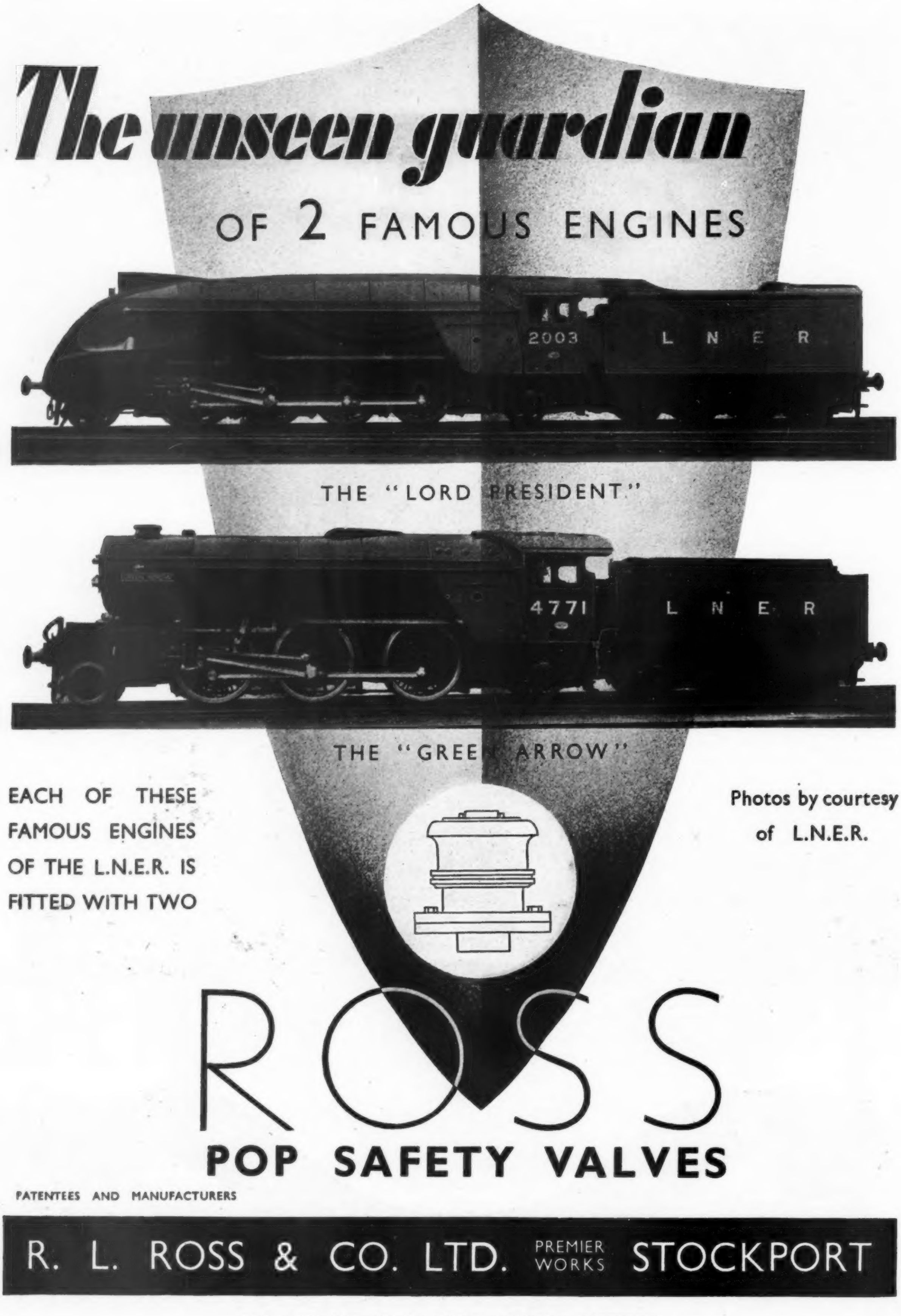
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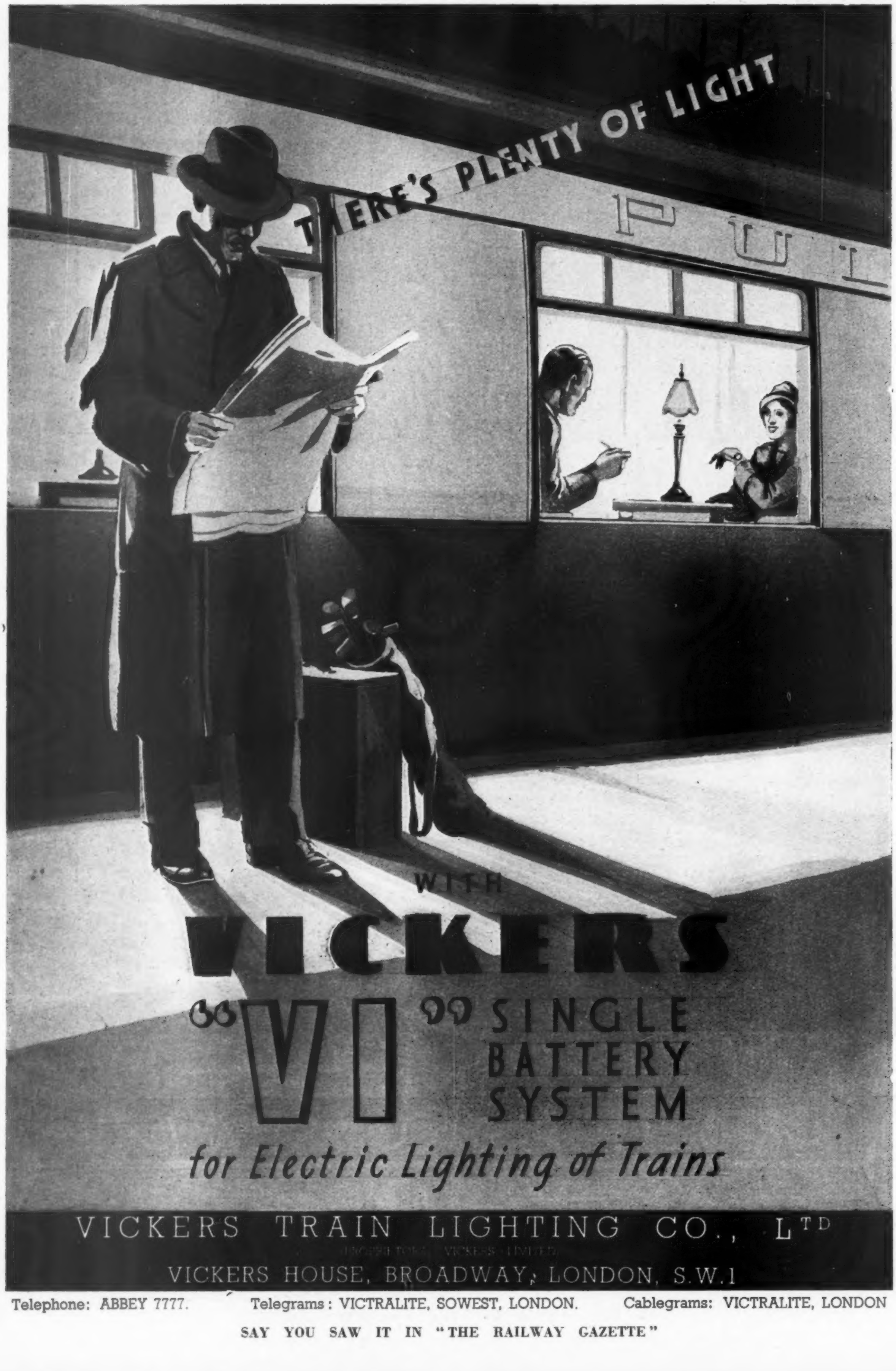
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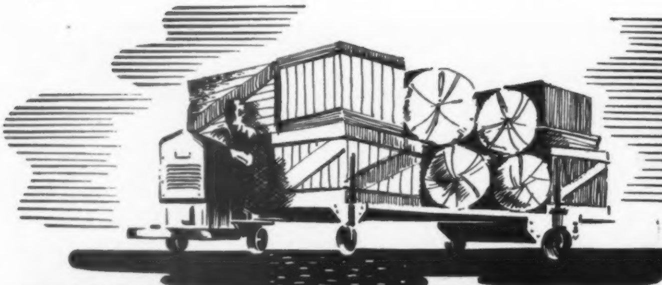

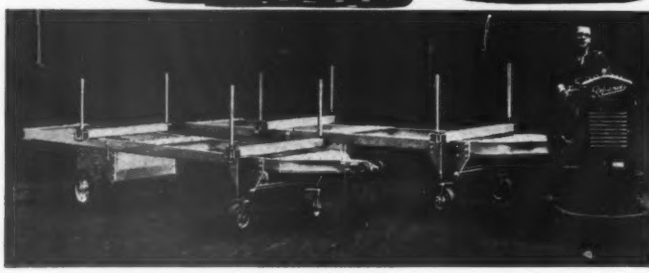

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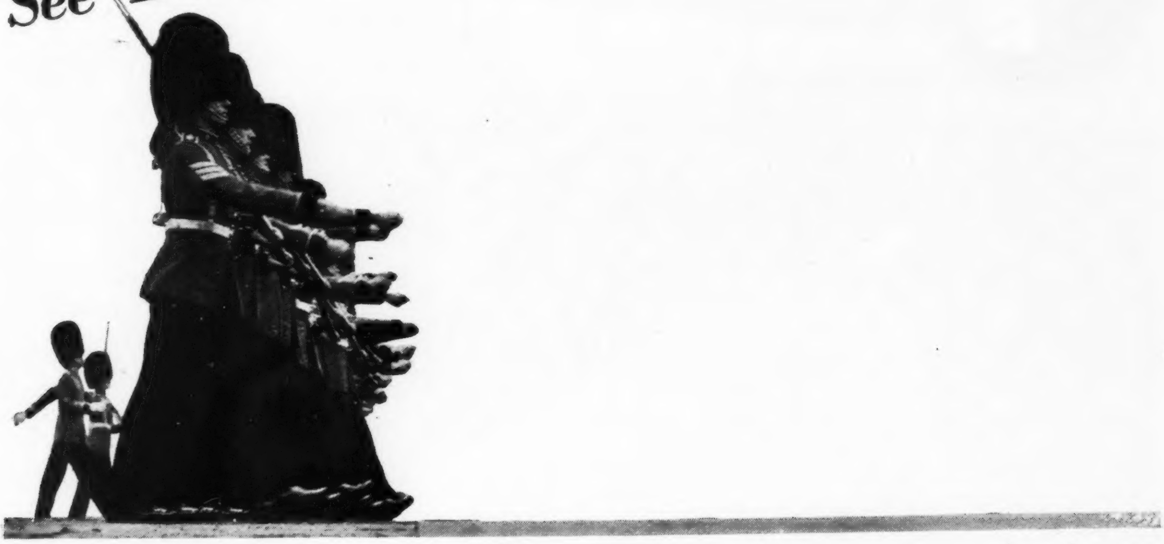

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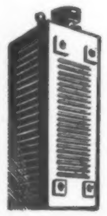

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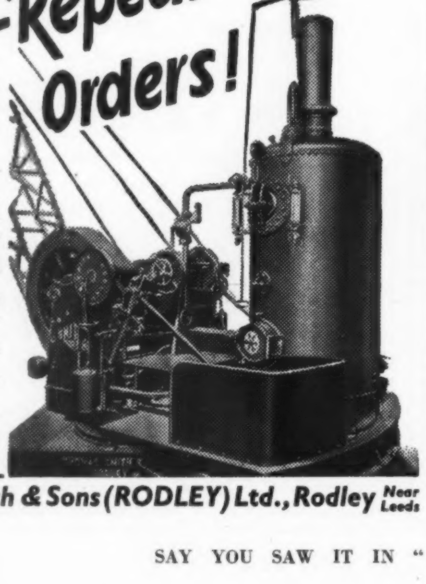

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